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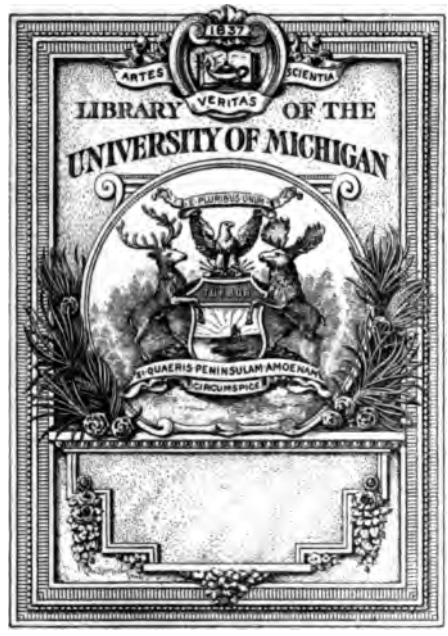
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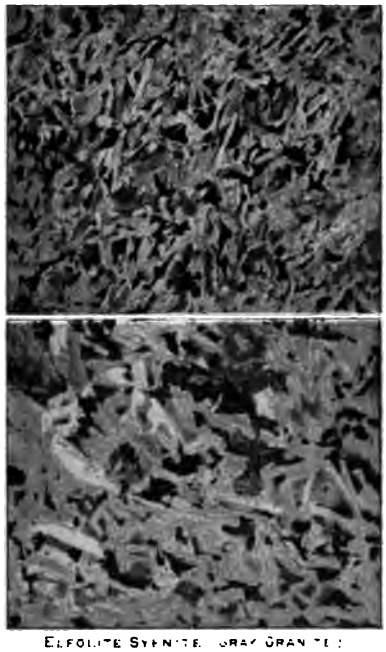
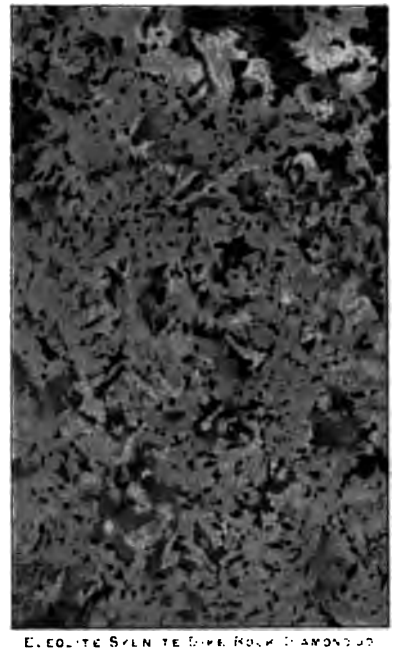
PULASKITE. BLUE GRANITE.
FOURCHE MT. REGION.

ELEOLITE SYENITE DIKE ROCK (BROWN GRANITE).
FOURCHE MT. REGION.



ELEOLITE SYENITE. (GRAY GRANITE.)
1 FOURCHE MT. REGION. 2 SALINE COUNTY REGION.



ELEOLITE SYENITE DIKE ROCK (DIAMOND OF
MAGNET COVE REGION.

ARKANSAS "GRANITE."

ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

ARKANSAS

FOR 1890

VOLUME II

THE IGNEOUS ROCKS OF ARKANSAS

By J. Francis Williams, Ph. D. C. E.

JOHN C. BRANNER, PH. D.
State Geologist

LITTLE ROCK
WOODRUFF PRINTING CO
1891

PUBLISHED NOVEMBER, 1891.

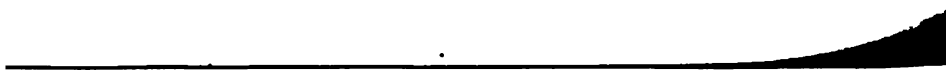
J. Frances Williams

In Memoriam

John Francis Williams

Born October 25 1862

Died November 9 1891



OFFICE OF THE GEOLOGICAL SURVEY OF ARKANSAS,
LITTLE ROCK, Feb 26th, 1891.

To His Excellency,

Hon. James P. Eagle,

Governor of Arkansas.

Sir:

I have the honor to submit herewith Volume II. of my annual report for 1890, and to remain,

Your obedient servant,

JOHN C. BRANNER,

State Geologist.

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ERRATA.

Page.

x. Under No. 14 the page should be 174.

xii. Seventh line, "eucalite" should be *eucolite*, and "montichellite" should be *monticellite*.

10. Eighth line, "primative" should be *primitive*.

17. Fifth line, "event" should be *evident*.

19. In the third foot-note, last two lines, there seems to be a mistake in calling the rock of Cleopatra's needle quartz porphyry. See Trans. Am. In. M. Eng., Vol. XI., 1882-3, pp. 367-379.

25. Twenty-second line, "phorphyritic" should be *porphyritic*.

89. Twelfth line, "microscopic" should be *macroscopic*.

89. In the table, first constituent, Sio_2 should be SiO.

208. In the foot-note, "1887" should be 1888.

225. In the analysis, last line, "hydroscopic" should be *hygroscopic*.

350. Second line from the bottom, "diopside" should be *plagioclase*.

373. Heading II. should be: *Ash-beds and detrital material of igneous origin*.

401. Eleventh line from the bottom, "Portugese" should be *Portuguese*.

441. Second line from bottom, "genitic" should be *genetic*.

438. In the sixth line, "17" should be 19.

439. In the ninth line, "Diller, J. C." should be *Diller, J. S.*

PREFACE.

The most important economic value of the present volume consists in:

I. The outlining in detail of all the "granites" of the state, showing a large supply of excellent building stone.

II. The determination of the crushing strength of those of the igneous rocks of the state that are available for building purposes.

III. Absorption tests made of the Arkansas "granites" and their comparison with other well known building stones.

The results of these tests are somewhat remarkable, showing, as they do, that the Arkansas "blue granite" (pulaskite) will withstand a higher pressure than any of the well known granites of the country. The low absorption of water by this rock is also greatly in its favor for building purposes, while its qualities on the whole rank it above all other known granites. (See p. 53.)

But while these igneous rocks of the state will doubtless become still more important in the future, their chief attraction to the geologist lies in their purely scientific interest—their history, petrography and mineralogy.

Certain localities in Arkansas have long been renowned for rare and beautiful minerals, and especialy have those from Magnet Cove been earnestly sought for by collectors and dealers in minerals. A large portion of the description of this interesting region in the present report is taken up with the minute chemical and crystallographic investigation of both the older and well known minerals, as well as the less known, or entirely unknown varieties which have been

brought to light by the researches of the Survey. The older minerals have been described and figured principally from what has already been written: thus brookite or arkansite, rutile, perofskite, schorlomite, eleolite, etc., had been so fully described that little was left for the present survey to do toward their investigation, while such minerals as eudialite, eucalite, manganopectolite, montichellite and others have afforded material for original investigation for the present workers.

The igneous rocks of the state, however, had been comparatively little studied; and with the exception of a few desultory notes scattered over a wide range of literature, no petrographic descriptions had been given of them. These descriptions, such as they are, were made mostly without the use of a microscope, and before petrographic methods and appliances had reached their present state of progress. Much space has therefore been devoted in this volume to detailed microscopic investigations of each of the numerous types of igneous rock. It has been found necessary in the course of these examinations to make use of many words and names which are unintelligible to one not a petrographer, but it has been deemed best to attempt no popular explanation of these terms, as such an attempt would leave the reader, unless equipped with a petrographic microscope and the necessary literature without any clearer idea of the subject.

It has been found necessary to coin several new rock names for species which could not well be described by the compounding system used in general throughout the report; thus, pulaskite, fourchite and ouachitite, names derived from political divisions or natural features of the state, have been made use of. Besides the names especially mentioned, a large number have been built up by the compounding of the name of the principal rock to which have been prefixed the names of one or more important minerals occurring in it. There are few regions of the world where so many varieties of rock occur within such small areas and in such

almost hopeless confusion, and where besides, disintegration and erosion have made a sharp separation of the various types almost impossible.

The Geological Survey of the State having been established chiefly for economic purposes, and its funds being too small for it to do much beside purely economic work, the study of the igneous rocks, and the scientific results here presented, would necessarily have been omitted had the Survey not been so fortunate as to secure the aid and valuable services as a volunteer assistant, of Dr. J. Francis Williams, the author of the present volume. In October, 1889, Dr. Williams began his studies of these rocks. The few observations made up to that time upon igneous rocks by other members of the Survey were placed in his hands; to this unimportant beginning he has added five months of field work and about nineteen months of office work. No one could possibly have labored more faithfully or more enthusiastically than he has done, and no one could have produced more satisfactory results within the time that he has been able to devote to it.

To those interested in petrography and mineralogy the scientific results of Dr. Williams' work need no commendation, while the people of the state who are not directly interested in purely scientific work will remember that these results must for all time reflect credit upon the state in which the work has been done, and under whose auspices the results are here published.

The topographic maps of the Fourche Mountain region and of the Magnet Cove region that had already been made by the Survey were placed at Dr. Williams' disposal when he began his work and appear in the present volume. (Maps II. and IV.) These maps were made by instrumental surveys (telemeter measurements) and the elevations determined by the use of the vertical arc. Stations that could be readily found were thus established over the entire area covered by the maps. Many of these stations were for the purpose of

locating partings between different kinds of rocks, while others were utilized afterward in doing the purely geological work. Mr. Louis L. Smith, who acted as rodman on the topographic survey, accompanied Dr. Williams, and by his acquaintance with the stations facilitated references to the instrumental lines. The location of the dikes and of the various rocks occurring in the Fourche Mountain and Magnet Cove areas is therefore as nearly accurate as it is possible to make it on maps of the scales used.

In Saline county no detailed topographic maps were made, and map III. was constructed by Dr. Williams by referring to the land lines of the United States land surveys.

The analyses given herein, and for which the Survey is responsible, have been made by Dr. Williams himself, by Dr. R. N. Brackett. the Chemist of the Survey, or by Prof. W. A. Noyes of the Rose Polytechnic Institute. Those of Dr. Williams were made in his own labaratory then at Clark University where his facilities for such work enabled him to guard against errors; owing to the lack of those facilities in the Survey's laboratory, analyses made by Dr. Brackett are to be credited with a less degree of accuracy.

The time which Dr. Williams could give to this work did not admit of his examining, in addition to the chief eruptive areas, all the dikes found in the state. Prof. J. F. Kemp, of Columbia College, who has given much attention to the study of dike rocks, very kindly undertook the examination of the samples collected from a great many of these dikes. The results of his work are given in Chapter XII., and also in Chapter XIII., where the last column but two shows which of them were examined by him and which by Dr. Williams. It will be seen that Professor Kemp has done a great deal of valuable work upon these rocks for which the Survey is greatly his debtor. It is not convenient to separate the determinations made by Prof. Kemp from those made by Dr. Williams, and for this reason the obser-

vations are all brought together in a single table, and credit given to each observer.

It should not be overlooked that the dikes mentioned in the table and those shown upon the maps make no pretention to being the only eruptive dikes in the state. Throughout the entire region of the Ouachita uplift there are probably scores of small dikes that have not been seen by the members of the Survey.

In the petrographical and mineralogical portion of the work the Survey has received the kind aid and suggestions of Professor H. Rosenbusch of Heidelberg, of Professor George H. Williams of Johns Hopkins University and of Professor Orville A. Derby of São Paulo, Brazil. Especial thanks are due to Prof. E. S. Dana of Yale College for the willingness with which he loaned the plates from his Brookite article, and to Dr. F. A. Genth for his kindness in furnishing unpublished analyses of several minerals from Magnet Cove.

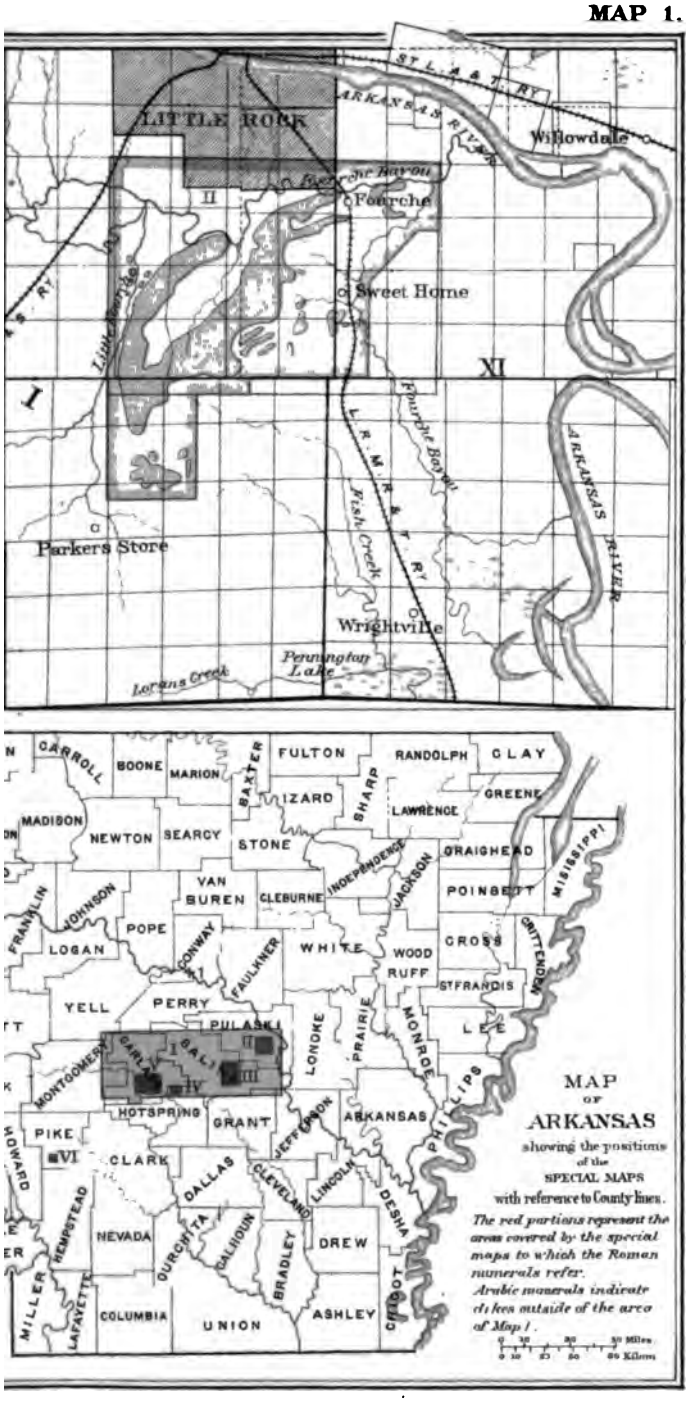
For the cordial aid and cooperation in carrying on the field work the Survey is under especial obligations to Mr. John F. Moore and to Mr. J. M. Henry of Magnet Cove.

The types and thin sections of rocks and minerals described in this volume are the personal property of Dr. Williams, and are now deposited in his petrographic laboratory at Cornell University, Ithaca, N. Y.

JOHN C. BRANNER,

State Geologist.

MAP 1.


LITTLE ROCK
ARKANSAS RIVER
ST L & S F RY
Willowdale
Fourche Bayou
Fourche
II
Sweet Home
Little Rock
XI
I
Fourche Bayou
L R M R & T RY
ARKANSAS RIVER
Fish Creek
Parkers Store
Wrightville
Pennington Lake
Lorans Creek
CARROLL
BOONE
MARION
BAXTER
FULTON
RANDOLPH
CLAY
GREENE
SHARP
IZARD
LAWRENCE
MADISON
NEWTON
SEARCY
STONE
CRAIGHEAD
INDEPENDENCE
JACKSON
MISSISSIPPI
POINSETT
FRANKLIN
JOHNSON
VAN BUREN
CLEBURNE
POPE
CONWAY
FAULKNER
WHITE
WOOD
CROSS
GRITTENDEN
LOGAN
RUFF
ST FRANCIS
YELL
PERRY
PULASKI
LONOKE
PRAIRIE
MONROE
LEE
MONTGOMERY
GARLAND
SALINE
PHILLIPS
HOTSPRING
GRANT
ARKANSAS
JEFFERSON
PIKE
VI
CLARK
DALLAS
CLEVELAND
LINCOLN
DESHA
HOWARD
NEVADA
OUACHITA
CALHOUN
BRADLEY
DREW
MILLER
HEMPSTEAD
LAFAYETTE
COLUMBIA
UNION
ASHLEY
CHICOT
MAP
OF
ARKANSAS
showing the positions
of the
SPECIAL MAPS
with reference to County lines.
The red portions represent the areas covered by the special maps to which the Roman numerals refer.
Arabic numerals indicate cities outside of the area of Map I.
0 10 20 30 40 50 Miles
0 10 20 30 40 60 Kilom

THE IGNEOUS ROCKS OF ARKANSAS.

By J. Francis Williams, Assistant Geologist.

CHAPTER I.

Geologic Occurrence of Igneous Rocks in Arkansas and Adjacent States.

Area and importance.—The total area of igneous rock exposed within the boundaries of the state of Arkansas does not exceed thirteen or fourteen square miles (3367 to 3626 hectares), but the value of these rocks as building and paving materials gives them great economic importance. Their formation and mode of occurrence are of especial scientific interest on account of their relation to the geologic history of the state at large; while their relations to each other are of even more importance from a purely petrographic standpoint, since they illustrate th relative positions of certain groups of igneous rocks whose mutual relations have been as yet but little studied.

Character of the rocks.—The igneous rocks of Arkansas all belong to the eleolite* syenites and their associated dike rocks. They are of the abyssal and intrusive classes, as distinguished from the metamorphic gneisses and schists and the true effusives. It has not been absolutely proved that some of the rocks did not form true eruptive masses, but on the other hand no proof that

* The spelling eleolite has been adopted throughout this report instead of elæolite in order to shorten the word and to make it correspond with the spelling of Paleozoic now in common use.

they did occur as such has been found, and since their crystalline structure points to a non-effusive origin, it may well be assumed that they all belong to the abyssal and intrusive rocks.

Geologic and geographic position.—The larger masses of igneous rocks occur on the southeastern side of the much disturbed and folded area known as the Ouachita uplift, which extends from the central portion of the state in a nearly due west direction to and across the Indian Territory boundary. The smaller dikes of intrusive rock are scattered here and there throughout the eastern half of the uplift and appear to be independent of the folds and ridges, which were formed long before the intrusion of the igneous masses.

The larger masses of igneous rock are, however, all situated in or near the main anticlinal axis of the uplift and it is probable that they were forced through at points, where, by reason of the folding, the strata were somewhat weakened. It will be shown later that it is probable that the greater part of the erosion which has modified the topography of this region to such an enormous extent had practically been completed before the intrusion of the igneous rocks.

Division of the eleolite syenites of Arkansas into areas.—The eleolite syenites were probably all produced from one magma, but since they occur in four well defined areas, and as the rocks which form these various areas differ greatly in their mineralogic composition, structure and occurrence, each of the regions forms a small independent group, which can hardly be sufficiently correlated with the others to allow of their all being described together.

These four regions are :

1. The Fourche Mountain or Pulaski County region.
2. The Saline County region.
3. The Magnet Cove region.
4. The Potash Sulphur Springs region.

Outside of these four typical regions there are many dikes of igneous rock which as far as their petrographic characteristics are concerned might be associated, as well with one group as with another, and which are, as a matter of fact, probably directly

connected with none of them, although formed from the same magma from which they all derived their material.

The differences in structure and mineralogic composition observed in the rocks of the four regions are due to differentiations in the original magma from which they were formed, and are attributable in many cases directly to the conditions under which they solidified.*

Age of the igneous rocks.—Although no very decisive data have been obtained for the exact determination of the time of the intrusion of the syenitic rocks, it can nevertheless be stated with a good deal of certainty that they were formed about the close of the Cretaceous period. The formation of these rocks did not take place at once, however, but continued over a considerable space of time.

Character of the adjacent sedimentary rocks.—The rocks which constitute the Ouachita uplift† consist principally of shales, sandstones and novaculites of the Lower Silurian system and these are bordered on all sides by the Lower Carboniferous or Mississippian rocks, which lie conformably upon the former. In the northern part of the area where the igneous rocks occur, and especially in the region about Little Rock, it is probable that the rocks through which the dikes and other eruptive masses have broken belong to the Lower Carboniferous or Mississippian series and not to the Lower Silurian. North of the Lower Carboniferous occur the Productive Coal Measures in which are located the coal deposits of the state. These are situated in a large synclinal basin which extends nearly half way across the state from its western boundary and is bordered on all sides, except the west, where it extends into Indian Territory, by the Barren Coal Measures. North of this the Lower Silurian rocks form a wide belt and extend to the northern boundary of the state.

Igneous rocks in Missouri.—In the southeastern part of

* Compare "On the Crystallization of Igneous Rocks," by Joseph P. Iddings, Phil. Soc. of Washington, Bulletin XI., 1889, p. 65; and "Ueber die Chemischen Beziehungen der Eruptivgesteine," von H. Rosenbusch, Mineral u. Petrogr. Mittheil., Band XI., 1889, p. 144.

† For a detailed description of this region see Vol. III. of the annual report of Geol. Surv. of Arkansas, for 1890, by L. S. Griswold.

Missouri are large areas covered by Archean rocks consisting of granites and porphyries * and containing the well known iron ore deposits of Pilot Knob and Iron Mountain. These rocks have been shown to be of Archean age and to have been overlaid by the Lower Silurian † rocks, which in that part of the country, have been but little disturbed since their deposition.

Igneous rocks in Indian Territory.—Similar Archean rocks have been found on Spavinaw Creek‡ in Indian Territory, just west of the northwestern corner of Arkansas, but nowhere within the latter state have Archean rocks been found.

Another mass of granite|| occurs in Indian Territory two hundred miles south of the exposure on Spavinaw Creek and extending for about forty miles in a westerly direction. These rocks are described as granites many of which are of a highly feldspathic type, and are cut by dikes of other igneous rock. It is not quite clear from Hill's description to what age he ascribes the granite, for he says, "From near the above mentioned railroad (M., K. & T. Ry.) at New Boggy Depot, west to Tishomingo near the Atchison, Topeka and Santa Fe road, is a superb ridge of granite forty miles in length interspersed with dikes, and completely cutting through the strike of the Coal Measures, and ending the Fort Smith–McAllister coal field. This granite is of many species and highly feldspathic. Resting upon this granite north of Tishomingo, and increasing in area westward is a superb region of folds of fossiliferous Silurian limestones and shales, with possibly earlier rocks, constituting the Arbuckle–Wichita mountain system." From this it would appear that the rocks are of pre-Silurian age and that the cutting off of the coal measures was due to a fault and not to the intrusion of the igneous rock. It is possible that these rocks belong to the Missouri system of Archean granites.

*A Contribution to the Archæan Geology of Missouri, by Erasmus Haworth, American Geologist, Vol. I., 1888, pp. 280 and 363. On page 281 of the paper mentioned, there is found a list of the most important literature on the subject of these rocks.

† These are marked Cambrian on the Geological Map of the United States issued in the 5th Annual Report of the Director of the U. S. G. S., Washington, 1885.

‡ Second Rep. of a Geol. Reconnoissance of the Middle and Southern Counties of Arkansas, by David Dale Owen, 1860, pp. 16 and 408.

|| Exploration of the Indian Territory and the Medial Third of the Red River by R. T. *Hill. Am. Geologist*, Vol. VI., 1890, p. 252.

Tertiary and Pleistocene of Arkansas.—All of the Paleozoic formations in Arkansas and southern Missouri are cut off on the eastern side by Tertiary and Pleistocene deposits, and the border line between them and the latter is approximately parallel to the course of the Mississippi River, until the center of the state is reached and it then turns more to the southwest. In Pulaski and Saline counties these deposits directly overlie the igneous rocks, and show that they were deposited after the intrusion of the latter.

Cretaceous in Arkansas.—The Ouachita uplift is bounded on the south by a band of Lower Carboniferous rocks and the latter are in turn cut off on the south by the Cretaceous* deposits of southwestern Arkansas which lie interposed between them and the Pleistocene deposits further south. These Cretaceous rocks are of especial importance, as indicating the age of the igneous rocks found in Pike county, Arkansas. The latter break through the Cretaceous beds, and show conclusively that they are posterior to them. It is, however, impossible to decide whether or not these peridotites of Pike county should be correlated with any of the other igneous intrusions found within the state of Arkansas.

Igneous rocks of Texas.—The Cretaceous formation extends through southwestern Arkansas and thence south into Texas. At several places igneous intrusions have been noted and one of especial interest near Austin, called Pilot Knob,† has been described by R. T. Hill, as having appeared as a true eruptive rock, during Cretaceous times. The rock is described by J. F. Kemp as a nepheline basalt, and it is possible that it may have been formed at the same time as some of the dikes and intrusions in Arkansas. Other intrusions of this character in the Texas Cretaceous are reported to be numerous, but their petrographic characteristics have not as yet been worked out.

Besides these intrusions of igneous rocks large masses of

* See the report on the Neozoic Geology of Southwestern Arkansas, by Robert T. Hill, Annual Report of the Geolog. Survey of Arkansas for 1888, Vol. II.

† Pilot Knob: A Marine Cretaceous Volcano, by Robert T. Hill, with Notes on its Petrography by J. F. Kemp, Am. Geologist, Vol. VI., 1890, p. 286.

pre-Cambrian rocks occur in the Central Mineral Region* of Texas, which comprises a part of Burnet, Mason and Llano counties.

Conclusions.—It thus appears that the eleolite syenites and the associated dike rocks of Arkansas form a unique group situated in an area, on all sides of which (except perhaps the south) igneous rocks of an entirely different character are found. That such an area of igneous rock is of great interest, not only from an economic, but also from a scientific point of view need hardly be emphasized.

* First Annual Report of the Geological Survey of Texas, 1889. E. T. Dumble, State Geologist, 1889, p. 239, Report by T. B. Comstock.

CHAPTER II.

General Literature on the Igneous Rocks of Arkansas.

Macrery.—The earliest mention of igneous rock in the state of Arkansas, then called the Territory of Louisiana, * which has been found was made by Joseph Macrery, M. D., † of Natchez, Mississippi Territory, in the year 1806. Macrery writes that he received his information from a certain "Major E., a gentleman of the first respectability in this territory," who visited the Springs in 1804, in company with a party of gentlemen from Mississippi. He then proceeds to describe the hot springs and their surroundings. He says (p. 48), "Silex or flint with its various combinations, often in the form of granite, is the stone most commonly met with." He describes among other specimens brought him, "Feldspar of a white, inclining to a red color, granulated texture, the surface covered with crystals of a rectangular form and very brilliant; black schorl, with pieces of quartz intermixed." He then says, "Volcanic productions are common. The face of the country bears strong marks of fire. A rapid decomposition of mineral bodies below the surface still appears to go on." It appears from the foregoing sentences that Major E. must have passed through Magnet Cove on his way to Hot Springs. The next statement appears to be a little out of keeping with what has since been found near Hot Springs, but it is quoted as it was written. It runs as follows:

* All that portion of the United States which lies west of the Mississippi River, and is bounded on the south by the Gulf of Mexico and Mexico, as it then existed, and by Canada on the north, was purchased from France in 1803, and in 1805 all that portion of it north of the present Louisiana state line was organized as the Territory of Louisiana, being what had previously been known as the District of Louisiana.

† A description of the Hot Springs and Volcanic Appearances in the Country adjoining the River Ouachitta in Louisiana. Communicated in a letter from Joseph Macrery, M. D., of Natchez, to Dr. Miller. New York Medical Repository, Vol. III., 1806, pp. 47-50.

"Major E., during his stay last summer at the springs, witnessed a great explosion of one of the mountains in the vicinity, attended with the sensation of an earthquake. An immense column of flame and smoke was seen to ascend a great distance: one of his hunters was near the place at the time. He visited the mountain the day after the eruption and observed lava still flowing in the fissure caused by the explosion."

Schoolcraft.—In 1819 Henry R. Schoolcraft published the results of two years travel and investigation in the territories* of Missouri and Arkansas.† On page 190 he mentions mica as being found at the "Hot Springs of Washitaw." He states that "the lamina are small, extremely flexible, of a greenish yellow color and admitting very little light through their broader faces." On page 192 he describes lodestone (native magnet) and states that this substance is found at a place called Cove, fifteen miles below the Hot Springs in Clark County (then embracing much more territory than now). He says, "The quantity is represented as very great and it possesses a strong magnetic power." He notes that other ores of iron, pyrites, quartz, white vitriol, etc., are found at the same place. On page 209, under the head of sulphate of zinc (white vitriol), he says, "On the authority of Dr. Andrews, of Mount Prairie, on the Red River, I mention the existence of native sulphate of zinc on the Washitaw River in Clark County, Arkansaw Territory. It is found in a highly interesting section of country about fifteen miles below the Hot Springs, and which also affords iron, loadstone, novaculite, quartz, mica, &c. The rock formation is argillaceous slate traversed by veins of white quartz." On the same authority, he mentions the existence of native sulphate of copper and of a saline material similar to Glauber's salts.

On page 262 under the section head of "Hot Springs of

* While Schoolcraft was making his observations,—viz., 1817 and 1818—the region was all known as Missouri Territory, but early in 1819 Arkansas Territory was formed and covered much the same area as that now occupied by the state of the same name. The State of Arkansas was admitted to the union in 1836.

† A View of the Lead Mines of Missouri including some observations on the mineralogy, geology, geography, antiquities, soil, climate, population and productions of Missouri and Arkansaw, and other sections of the Western country, By Henry R. Schoolcraft, New York (Chas. Wiley & Co.), 1819, (300 pages and three engravings).

Ouachitta (Washitaw)" he mentions the Cove fifteen miles below the springs and recapitulates the minerals found there, as given above.

Bringier.—A description of the minerals and rocks of Arkansas, and particularly of those of Magnet Cove was published in the year 1821.* The iron ore deposits of the "Cove of Wachitta" are mentioned and are said to yield a very fine quality of iron. The occurrence of both magnetite and a cellular limonite is noted. Masses of sulphate of lime, and talc (Mica? *Editors of Silliman's Journal*) in extraordinarily large plates or sheets are mentioned. The Cove is said to abound in kaolin and petunze of a very superior quality for the manufacture of porcelain. Native copper was reported to have been found there by an Indian. Pyrite and native copperas were also reported, as well as a white talcose earth, which was infusible before the blowpipe.

Burr mill stones were made from the rocks forming the hills about the "Wachitta Cove" and were pronounced to be of a very fine quality.

The editor of the journal in which this article appeared (Prof. Benjamin Silliman) states in regard to the above paper, that at his request, the Rev. Mr. Cornelius, who had in Series 1, Vol. I., pp. 214 and 317, of the American Journal of Science, published the results of his observations on some of the southern and southwestern states, sent him a letter, which he had received from L. Bringier, Esq., of Louisiana, and which embodied a large mass of information concerning those portions of the southwest which Cornelius himself did not visit. In regard to this letter, the editor writes: "Although somewhat immethodical, it abounds so much with interesting statements, that we have thought it better to publish it, with some alterations and omissions (agreeably to the author's permission communicated with the paper), rather than to attempt a new digest of the subjects, for Mr. Bringier appears to have contemplated little

* Notices of Geology, Mineralogy, Topography, Productions, and Aboriginal Inhabitants of the regions around the Mississippi and its confluent waters, in a letter from L. Bringier, Esq., of Louisiana, to Rev. Elias Cornelius. (The letter itself was dated March, 1818, so that these investigations evidently antedate those of Schoolcraft.)

Am. Jour. of Science (Silliman's Journal), Series 1, Vol. III., New Haven, 1821 pp. 15-47

more than the communication of *materials*, to be wrought into a different form."

The editor submitted the article, in the manuscript form, to "N. A. Ware, Esq., an intelligent and scientific gentleman, from Alabama," who gave his opinion on many facts stated in the manuscript; and his letter is published as a foot note to the main article. In this letter Ware states, "I have no doubt of the granite or primative mountains, on the Arkansas, and neighborhood." A careful perusal of the article, as it appears in print, reveals no mention of such granite by Bringier, and it is probable that it was omitted when the manuscript was revised. If Bringier saw granite on the Arkansas River, or in its immediate neighborhood, and reported it in his letter to Cornelius, he certainly should have the credit of being the first person to mention the igneous rocks of the Fourche Mountain region.

Featherstonhaugh.—The earliest scientific description of the igneous rocks of Arkansas, was given by G. W. Featherstonhaugh, in a report* presented to the House of representatives in 1835. The examination of the country on which this report was based, was made inside of six months, including the time required for a trip to and from Washington. The entire distance was traveled upon horse-back and a profile was drawn illustrating the geology of the whole route from the Atlantic coast by way of St. Louis to Arkansas and Texas. It is remarkable to note how well Featherstonhaugh observed, and notwithstanding the obstacles with which he had to contend, in the form of wild and unopened country, and poor traveling facilities, how much territory he was able to cover and investigate.

He describes Magnet Cove (page 62) and mentions its nearly circular form and compares it to the Virginia and Tennessee coves. He remarks the presence of deciduous trees on the igneous rocks, while the siliceous rocks are covered with

* Geological Report of an examination made in 1834 of the Elevated Country between the Missouri and Red Rivers, by G. W. Featherstonhaugh, U. S. Geologist. Washington, (Gales and Seaton), 1835, (97 pages with a section).

pine. He notes "greenstone," containing much crystallized hornblende, and "a coarse grained syenite consisting of red feldspar, hornblende, mica, and some quartz." He then mentions the magnetic iron ore, from which he says the Cove took the name of "Magnet Cove," by which it was then known. He refers the rock of the Cove to the older intrusive rocks and, perhaps, to a very remote volcanic formation.

It is surprising that Featherstonhaugh makes no mention of the Fourche Cove and the Pulaski County syenite region, for W. B. Powell states (see below) that Featherstonhaugh was taken thither by Rev. W. W. Stevenson, of Little Rock, and had the whole region shown to him.

Powell.—In 1842 W. Byrd Powell, a professor of phrenology and geology in the Medical College of Louisiana, spent "a few weeks" at the Fourche Cove and then presented the results of his investigations, in the form of a pamphlet, to the Antiquarian and Natural History Society of the State of Arkansas.* He begins his account of the region with some general remarks on the use of geology and soon passes to the description of the Cove and its rocks. He connects the rocks of this region with those, which he had heard of as existing in Saline county, Magnet Cove, and the Little Missouri (Pike county) region and of which he had seen a few hand specimens, and states that all idea of intrusiveness, as suggested by Featherstonhaugh for the Magnet Cove region, is disproved by the great extent of country, which these rocks cover, as well as by their "highly perfect and crystalline character." He states that he considers them as of "primitive origin."

In describing the rock itself, he speaks of the granite as being of the feldspathic variety, and states that it contains in some places mica and in others hornblende, while in both cases it is free from quartz. He describes several other forms of rock under

* A Geological Report upon the Fourche Cove and Its Immediate Vicinity, with so me remarks upon their importance to the Science of Geology and upon the value of their Productions to the Arts of civilized Society, accompanied with a suit of specimens and a catalogue: presented to the "Antiquarian and Natural History Society of the State of Arkansas," by W. Byrd Powell, M. D., Little Rock, 1842. (22 pages and sketch map).

names the exact significance of which he evidently did not know. Among these may be mentioned *corneans, hornblende rock, basalt, greenstone, gneiss and grauwacke.* He points out many localities where technically useful materials may be obtained, and closes by giving a list of 120 specimens, which were presented to the Antiquarian Society of Little Rock and adds a sketch map of the region on which the localities, where the specimens were collected, are indicated by letters.

Shepard.—In 1846 * Prof. C. U. Shepard mentioned the occurrence of eleolite as a mineral at Magnet Cove and described several varieties of rock from Pulaski, Saline and Hot Spring counties as well as that from the Little Missouri River in Pike county. After visiting the locality in 1861, he speaks † of "Eudialyte imbedded in feldspar and associated with ægirine, the three belonging to the extensive elæolite rock of that remarkable region."

Engleman.—In 1851 Dr. George Engleman added some notes to Dr. H. King's paper, entitled "Some Remarks on the Geology of the State of Missouri,"‡ read at the Cincinnati Meeting of the American Association for the Advancement of Science. In these notes he mentions two of the syenite localities of Arkansas, and also describes the black micaceous rock of the state quite correctly. He says: "Within the unfossiliferous sedimentary rocks, I found a beautiful gray syenite,‖ sometimes changed into large masses of kaolin; and at another locality, 'Magnet Cove,' a succession of hills or knobs of black and white syenite mostly coarse grained, and of true trachyte, with large glassy feldspar. At other places anomalous rocks, of a singular structure were observed, having sometimes the appearance of amygdaloid, probably metamorphic. Porphyry and granite (without mica) which occur in the syenite of Missouri, I have not seen in Arkansas. The connection of these rocks with the stratified rocks has not been observed."

* On three new mineral species from Arkansas and the discovery of the Diamond in North Carolina, By C. U. Shepard, Am. Jour. Sci., Series 2, Vol. II., 1846, p. 249.

† Mineralogical Notes by C. U. Shepard, Am. Jour. Sci., Series 2, Vol. XXXVII., 1864, p. 407.

‡ Proceedings of the A. A. A. S., Vol. V., 1851, p. 182. Note on page 199.

‖ Fourche Mountain region.

"In the clay slate, and probably in it only, trap dikes are very common, especially near the Saline River. Sometimes these dikes, one or more together, traverse the strata of slate leaving them undisturbed on the edges, or in other localities, bending them upward on both sides of the dike. In other cases, one or more, (I have seen as many as four) strata of trap are wedged in between the strata of slate, apparently interstratified with them, but evidently forced in after the formation of the slate. In one locality I have found the ends of these strata running out rounded, as if they had been forced in in a semi-fluid consistency; and not changing the lithological character of the clay slate. In another, a mass of several feet thick had split in hundreds of small veins, only a few lines wide, but easily distinguished from the *altered* and *stratified* rock. These trap rocks are very remarkable on account of the presence of black mica which in some of them occurs in great abundance, and in large and finely formed crystals."

Engleman then proceeds to compare the magnetic iron ore of Magnet Cove with the deposits of iron ore near Lake Superior and especially with those of Missouri. He considers the granites and Silurian limestone on the Llano River in Texas to be connected with the granite and syenite of Arkansas, Missouri, and of Lake Superior, and perhaps with that of the plateau of Mexico.

Barney.—In 1852 the Secretary of War communicated to the 32nd, Congress* a report by Joshua Barney, on a Survey of a Route for a Railroad from the Valley of the Mississippi to the Pacific Ocean, commencing at St. Louis, Mo.

In this Barney says: "The hills bordering the valley of the Fourche Bayou are very high and those on the right of the stream appear to be one mass of granite. There is as isolated hill within four miles of the Arkansas on the right bank of the Fourche, called Iron Mountain, which rests on a base of granite of very superior quality for building, from which blocks of any dimension can be obtained. The hill rises to a height of 200 to 300 feet."

Warder.—In 1854 J. A. Warder published a pamphlet on

* Exec. Documents, No. 49, Senate, p. 91.

the geology of the Arkansas River,* in which he mentions the syenite of Fourche Mountain, as a "veritable granite" and ascribes to its intrusion, the formation of the numerous folds and veins in the region about Little Rock.

Owen.—In 1860 appeared the second report† of the first geological survey of the state under David D. Owen, in which he, first of all (page 16), states in general terms, his opinion that there is a great "granitic axis which gives to Arkansas its peculiar geographical features and has greatly disturbed and modified its geological rock-formations, aided, undoubtedly, by a continuous widespread, underground extension of these igneous rocks, on a platform of which the stratified rocks of Arkansas repose, at a greater or less depth, conforming to the contour of the waved surface." He suggests the probable existence of another granitic axis further to the north, but states that the granite only appears on the surface at a point near the mouth of Spavinaw Creek in Indian Territory.‡ After ascribing the cause of the hot water outflow at Hot Springs to the same igneous action, which produced these granite protrusions he states that he has discovered no outcrop of "real igneous or crystalline rocks nearer than Tiga§ Creek on the borders of Magnet Cove, a distance of ten miles in a direct line from the Hot Springs." (p. 24). He next describes Magnet Cove (pp. 30-31) and gives a list of the more important minerals and rocks that occur there. As these must be referred to later under the head of Magnet Cove, they may be passed over here without further mention. Owen mentions (p. 31) the beauty of the granites of the Fourche Cove and Saline County regions and shows that they might be very profitably quarried at either place. He next describes briefly (p. 32)

* A Geological Reconnoissance of the Arkansas River, by Prof. J. A. Warder of Cincinnati, O., Cleveland, O., 1854, (27 pages with 22 woodcuts), pp. 10 to 12.

† Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas, made during the years 1859 and 1860, by David Dale Owen, and others. Philadelphia, (Sherman & Son) 1860, (433 pages with numerous chromolithographs).

‡ Edward T. Cox, assistant geologist under Dr. Owen, after the latter's death, visited Spavinaw Creek (Owen's Report, p. 408.) and followed its course for about thirteen miles, but contrary to his expectations, without finding any of the "Missouri granite" inside of the borders of Arkansas.

§ Tiga or Teager. (See chapter X).

a small area of igneous rock in Pike county, which he calls "porphyritic greenstones" and "trachytic rocks."

Owen states (p. 32) that only two instances of "overlying crystalline rocks" are known, one of which is exposed on the southwest bank of the Ouachita River near Mill Gap, one mile from Magnet Cove. He says: "Here a hard, tough, hornblendic rock, with large flakes, and crystals of jet black mica, is seen reposing conformably on the comparatively soft layers of slate, inclined at an angle of 10° to 11°, dipping into the Ouachita River obliquely across the channel."

Under the head of "Remarks on the Various Counties," he repeats some of his previous remarks about the special regions referred to. Thus (p. 69) he describes at some length* the rocks and minerals of Fourche Cove, mentioning a black porphyritic basalt, as well as several varieties of granite.

In that portion of the report devoted to Hot Spring county, he returns to the subject of Magnet Cove (pp. 104 and 105) and then passes to a description of the several "Chalybeate springs" (p. 106) on the east side of the Hot Springs ridge. He notes that, "near Fairchild's Mineral Spring the rock is a kind of quartz porphyry, amongst which a calc spar rock is also found."

In Saline county he mentions (p. 108) the "protrusions" of granite in 2 S., 14 W., and notes an occurrence of a trap and hornblende dike in 1 N., 17 W., section 32. This he states to be of "undoubted igneous origin." He also mentions loose pieces of granite on Lindsay's branch of the South Fork of the Saline River near Mrs. Richardson's, and a dike of black crystalline basaltic rock, lying conformably with the argillaceous rock of the region.

Under the head of Pike county, he states (p. 124) that a shaft had been sunk twenty-one feet through the already mentioned porphyritic rock without striking any regular ore vein, and (p. 127) that a quarter of a mile south of the eruptive area already described, there was an indication of an eruption of rock, which had never reached the surface.

* This will be discussed more in detail under the head of the igneous rocks of the Fourche Mountain region (see chapter III).

Under the heading, "Survey of The Fourche Cove in Pulaski County, Arkansas, by Joseph Lesley, Topographical Assistant," (pp. 153-162) a short description of the topography of the region and a few notes on the geology are given. At the end of this notice the following sentence occurs: "The contour-line relief map of this district, if published, will be found at the end of the volume." *

Cutter.—A guide to Hot Springs † was published in 1874 in which Magnet Cove and the Hot Springs region is described (pages 71-80). The description is copied directly from Owen's Report, but a few notes are added, which are of interest in the consideration of the igneous rocks of that locality. In referring to Owen's statement, that no crystalline rocks had been observed by him nearer Hot Springs than "Tiga Creek," Cutter remarks (p. 74): "They have since been found in the mountains north and east of Hot Springs, within two or three miles, but not in any great quantity and small in size."

On page 77 Cutter states that Owen was mistaken in regard to the depth to which the lodestone at Magnet Cove extends. He says: "The loadstones are now quite scarce, and the Professor was mistaken in regard to the iron ore extending to any great depth. Dr. G. W. Lawrence, who now owns part of the Mitchell farm, says it is confined to within a few feet of the surface. The writer (Cutter) examined several places and could find none three to five feet below the surface; but it does exist in other parts of the Cove and on the hills surrounding it." On the next page Cutter mentions the idea held by many, that nickle and gold are to be found on the farm of James Henry; and notes the fact that during the war sulphur was manufactured from pyrite found there.

Harvey.—In 1886 F. L. Harvey published a pamphlet on the

* Owing to the incomplete state in which the Survey was left by the death of Professor Owen, this map was never published, and the original of it was probably taken to Philadelphia by Mr. Lesley, the topographer, and cannot now be found.

† The Hot Springs (of Arkansas) as they are, Illustrated, A History and Guide, By Chas. Cutter, Second Edition, St. Louis, Mo. (Southwestern Book and Pub. Co.), 1875, (109 pages and 9 wood cuts).

"Minerals and Rocks of Arkansas."* After noting the various minerals found in the state, Harvey gives a list of the crystalline rocks with their localities. Among these he notes granite, porphyritic granite, graphic granite, syenite, hornblende rock, nephelitic granite, dolerite, etc. It is event that he only determined the above varieties macroscopically, for the use of the microscope would have brought him to a very different nomenclature.

Rosenbusch.—H. Rosenbusch in his Mikroskopische Physiographie der Massigen Gesteine† notes the occurrence of eleolite syenites (p. 91) from Hot Springs,‡ Arkansas, and under the head of phonolite (p. 631) states, that, according to a communication from H. Carvill Lewis, pseudomorphs of feldspar and muscovite after leucite occur in the Hot Springs region, and that this would indicate the presence there of a leucitophyr or a leucite phonolite. This would, he says, be the more interesting, from the fact that eleolite syenite is already known from that locality.

Comstock.—In 1888 volume I of the annual report of the Geological Survey of Arkansas appeared.§ It consists principally of a "Report upon Preliminary Examination of the Geology of Western Central Arkansas by Theo. B. Comstock, Dr. Sc.," and in this occasional mention is made of igneous rocks. Thus (pages 7 to 11) the syenites in the neighborhood of Little Rock are described and the occurrence of porphyries and massive igneous rocks noted. The order of the overlying sedimentary rocks and their stratigraphic relation to the igneous rocks is also stated.

On pages 55 and 56 some granitic rocks about Potash Sulphur Springs are described and a few remarks about their mineralogic composition are added. Pages 81, 82 and 83 are devoted to a

* The Minerals and Rocks of Arkansas, A Catalogue of the Species, with localities and notes, by F. L. Harvey, B. Sc., Philadelphia, (Grant and Faires) 1886, (32 pages with 14 electrotypes of minerals taken from A. E. Foote's Catalogue of Minerals.)

† Mikroskopische Physiographie der Massigen Gesteine von H. Rosenbusch, Stuttgart, 1887.

‡ Almost all the minerals from Magnet Cove are known in Europe as from Hot Springs.

§ Annual report of the Geological Survey of Arkansas for 1888; John C. Branner, State Geologist, Vol. 1., 1888.

2 Geological; Vol. II., 1890.

description of Magnet Cove and the rocks of which it is composed, but the subject is treated only in a most general way and no attempt is made to trace out the igneous rocks nor to determine their petrographic characteristics.

The report is supplemented by a valuable list of minerals from all parts of the state. A large number of these come from Magnet Cove and include both the minerals of the igneous rocks as well as the metamorphic minerals.

Branner.—At the Cleveland meeting of the Am. Association for the Advancement of Science John C. Branner* stated, that although on the geological maps of the United States, the area about Little Rock, Ark., and another small region in the southwestern part of the state were generally represented as Archean, this was not the case, but that the crystalline rocks were injected into the Paleozoic strata, the exact age of which had not as yet been determined. He inclined to the opinion that the rocks through which igneous rocks protruded should be referred to the Lower Carboniferous series.

At the same meeting a paper on "Peridotites of Pike county, Arkansas, by John C. Branner and R. N. Brackett" was read, and an abstract of it appears on the same page as the preceding note. This paper was afterwards published in the American Journal of Science† and is incorporated in this report as chapter XIV. in essentially the same form in which it there appeared.

Day.—In 1890 the Mineral Resources of the U. S. for 1888‡ was published and under the head of granite, a description is given of the stone quarried by the Arkansas Granite Company of Little Rock.§ It is here stated that this rock is not a true granite, but a syenite, and an analysis obtained from the laboratory of the Geological Survey of Arkansas is published.

Other papers, which have appeared from time to time, are more limited in their scope and will be reviewed under the special subjects of which they treat.

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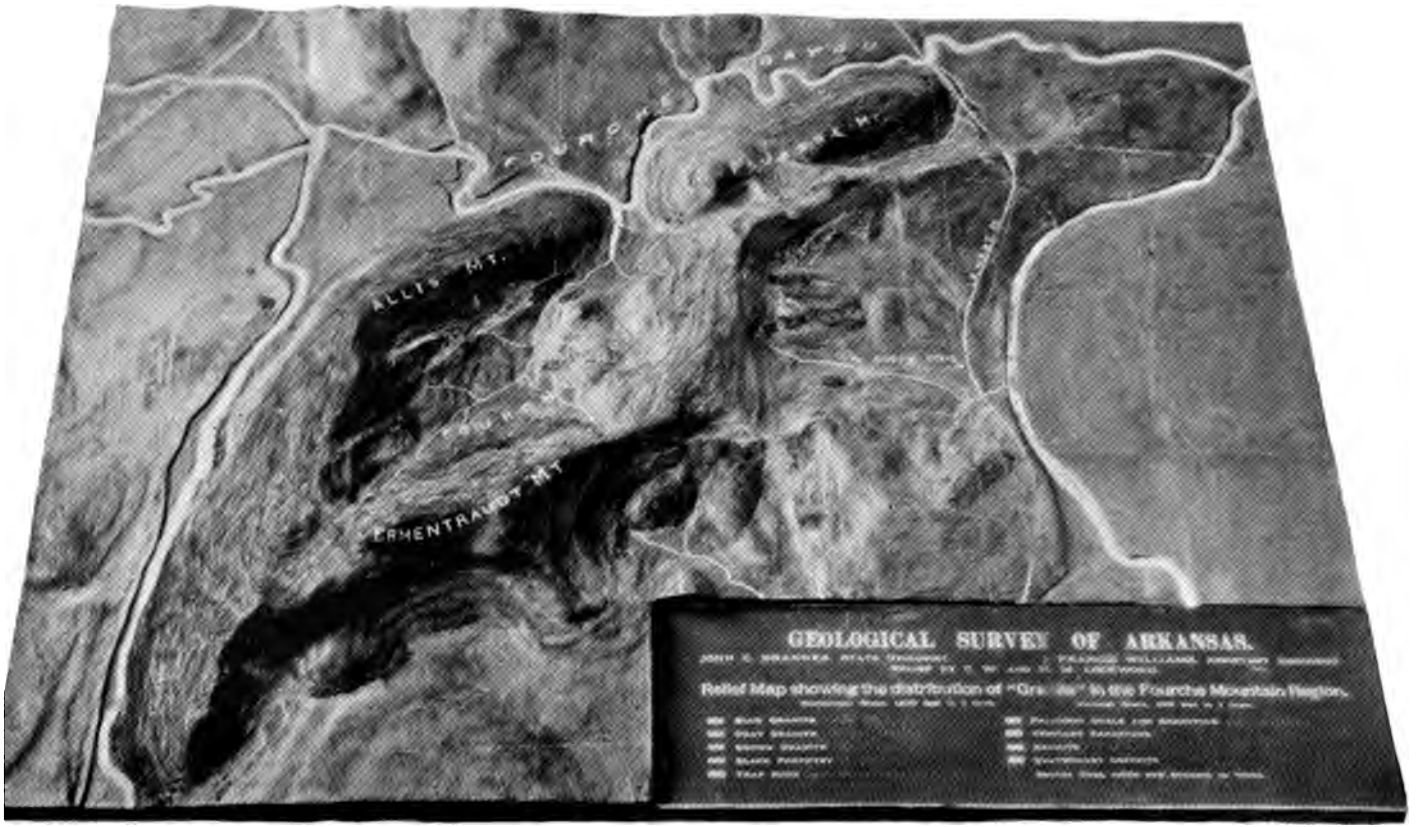
* The age of Crystalline Rocks of Arkansas, by John C. Branner. Proceedings A. A. A. S., Vol. XXXVII., (Cleveland, Ohio, 1888), Salem, Mass., 1889, p. 188.

† The Peridotite of Pike County, Arkansas, By J. C. Branner and R. N. Brackett. Am. Jour. Sci. Series 3, Vol. XXXVIII, 1889, pp. 50-59 with map.

‡ Dept. of the Interior, U. S. Geol. Survey. Mineral Resources of the U. S. Calendar year 1888, By David T. Day, Washington, 1890, p. 587.

§ *This company* is now absorbed by the Little Rock Granite Company.



RELIEF MAP OF THE FOURCHE MOUNTAIN REGION.

CHAPTER III.

Distribution of the Igneous Rocks in the Fourche Mountain Region.*

Fourche Mountain† is a mass of "granite"‡ 380 feet (117 meters) in height which is situated on the south side of the Fourche Bayou, about three miles (4.7 km) south of Little Rock. To the west of this and separated from it by a deep depression known as Fourche Cove, lies Allis Mountain,§ which, at its highest point, reaches an elevation of 520 feet (160 meters) above mean tide level on the Gulf of Mexico. The northern portion|| of Fourche Mountain has a general northeast and southwest direction, running parallel to the Fourche Bayou, a sluggish stream, which skirts its northern side and appears to form the limit of the granite areas in that direction. This part of the mountain forms a flat topped ridge (south ½ of sec. 13) nearly a mile (1.6 km) in length. It falls off steeply on both sides, and at the northeast end descends abruptly to the flat bottom-land, at which point the line of the Little Rock, Missis-

* See map II. and plate 2 in this report.

† There are two Fourche Mountains in Arkansas; one is a range of mountains in Perry, Yell, Montgomery and Polk counties; the other, a small one, is the one referred to in this report and is situated in Pulaski county.

‡ The word "granite" is here employed not in its petrographic sense, but as it is continually used by the inhabitants of this region to denote the syenitic rocks, quarried on these mountains. Throughout this report the word *syenite* will be used to indicate a rock consisting of *orthoclase* (alkali feldspar), *biotite* (black mica), *amphibole* (hornblende), and *pyroxene* (augite), in varying proportions, and it may therefore be designated as a *quartzless granite*. The older use of the word *syenite*, to designate a *hornblendic granite*, has been abandoned by all modern petrographers, but, as the older text books on geology usually give such a definition for this rock, and mention Syene in Egypt as a typical locality, it may be stated that the rock from Syene, from which the Cleopatra's needles in New York, London, Rome, etc., were quarried, is not a syenite, according to modern petrographic nomenclature, but a quartz porphyry.

§ Also called Granite Mountain.

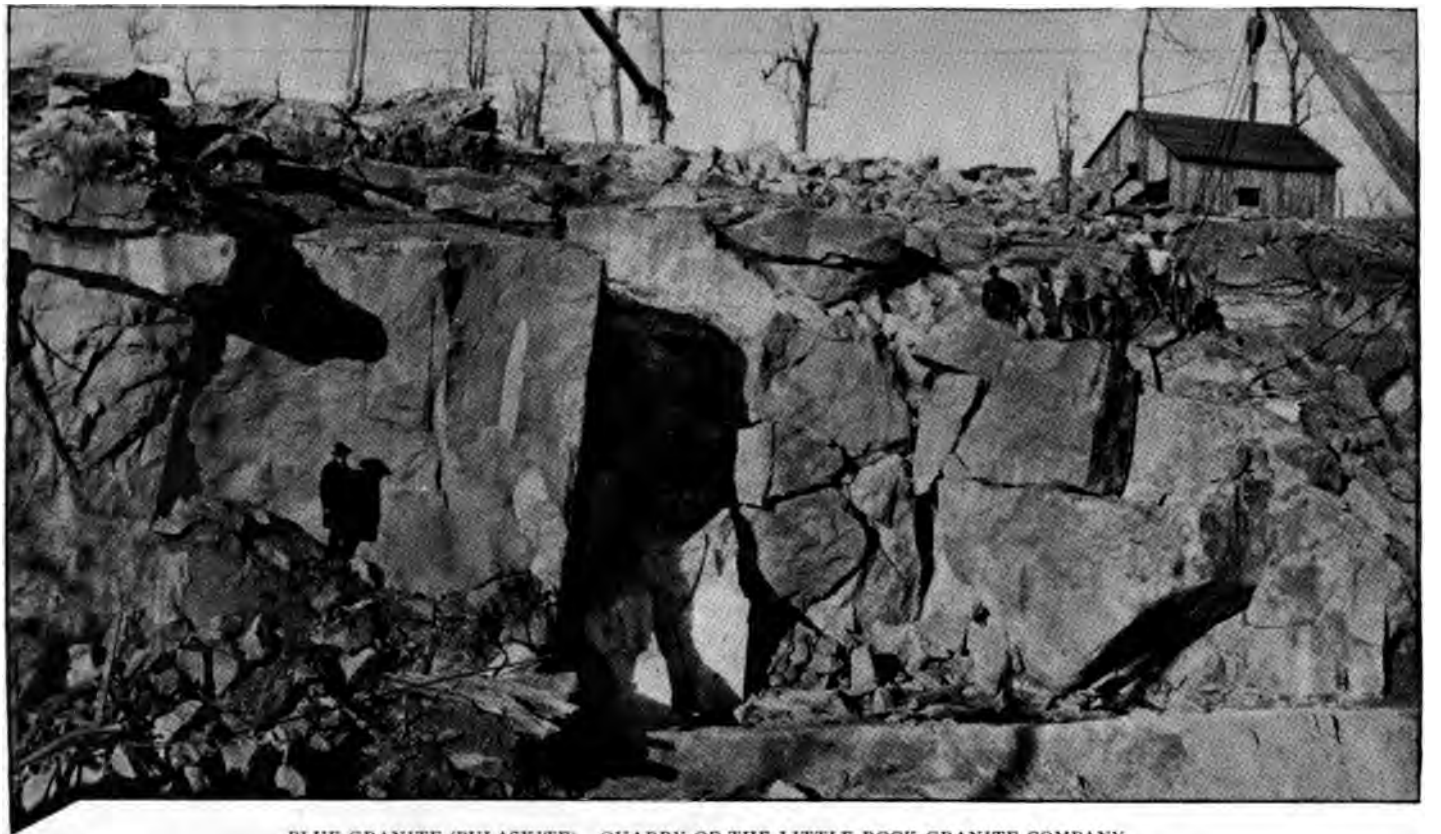
|| This small portion of the Fourche Mountain region is called Fourche Mountain in distinction to other parts of the ridge which also have special names.

sippi River and Texas Railway just touches the east end of the granite. The prevailing rock of the Fourche Mountain region is the so-called "blue granite,"* which has already been quarried at several points, as for example, at the quarry of the Little Rock Granite Company on the south side of the mountain. The illustration (plate 3) shows the present appearance of a portion of this quarry. On the south side of the quarry a dike of fine grained light colored syenite rock occurs. It has forced its way through the blue rock, but seems to have caused very little disturbance. Segregation veins of coarse material are found irregularly distributed through the blue granite (pulaskite) here and elsewhere on the ridge.

Along the top of Fourche Mountain proper there are scattered several boulders of light colored, coarse grained rock (miarolitic eleolite syenite) which is evidently quite different from the mass of the blue rock, which makes up the ridge, and whose relation to the latter will be considered later.

About the center of the top of the ridge just described is a slight depression (N. W. ¼ of sec. 24) through which the turnpike crosses to the south. This flat and slightly lower part of the hill is covered with yellow sand, mould and loose blocks of granite. It is somewhat marshy and forms the drainage basin for the three higher portions of the mountain surrounding it. These higher points consist of the two portions of the ridge just mentioned, and a third ridge to the south of, and almost parallel with, the main one. Between this and the main ridge lies a narrow valley which is covered with sand and alluvium. Near its lower or eastern end, appear two or three small areas of brown granite (eleolite syenite dike rock) (chap. IV. II. C. 1). The ridge just mentioned is from 400 to 600 feet (122 to 183 meters) wide, and extends a little further to the east than the first one. It is bounded on both sides by sand, which on the south in some places reaches, almost if not quite, to its crest. The extreme eastern end of this ridge is cut through by the railway and the

* This is that rock, which is described later under the name of pulaskite. By pulaskite is understood a rock made up of orthoclase, pyroxene (var. diopside and ægirite), amphibole (var. arfvedsonite) and a little eleolite, or its decomposition product, analcite.



BLUE GRANITE (PULASKITE). QUARRY OF THE LITTLE ROCK GRANITE COMPANY.

cut exposes a deposit of Pleistocene gravel overlying the blue granite (pulaskite). The latter shows evidence of having, at some time previous to the deposition of the overlying sedimentary material, formed a beach covered with boulders which were more or less rounded by the action of the waves. By the deposition of the Pleistocene material the spaces between the boulders and the hollows in the solid rock were filled with gravel, and this in time became solidified by the infiltration of ferruginous matter. The boulders themselves have continued to decay so that they are now surrounded by shells of soft decomposed material.

Although the rock at this point has been spoken of above, as blue granite (pulaskite), it approaches very closely to the gray variety, in its texture and mineral composition. It seems to hold an intermediate position between the two varieties, and might well be designated as a transition rock. The rock is not uniform in texture, for in some parts it is much more like the blue granite (pulaskite), while other portions of it, only an inch or so away, may have an almost perfect gray granite (eleolite syenite) structure. It is from the decomposition of such rock that the material for some of the analyses of decomposed granite (syenite) and kaolin was obtained. (See chapter IV).

East of the railway lies a low marshy tract of land, beyond which rises a low hill [320 feet (98 meters)], (S.E. ¼ of sec. 18), the north side of which, almost down to the Fourche Bayou, is covered with blue granite (pulaskite). At the lowest point in a small ravine cutting into the north side of this hill, a small flat patch of brown granite (eleolite syenite dike rock) appears. On the south side of this hill there is a second outcrop of blue granite (pulaskite) which extends nearly to its foot and to the Fourche Bayou as it curves around toward the southwest.

The main granite (syenite) ridge, from the west end of the ridge already described, extends almost due south for a distance of two miles (3.3 km), branching out here and there into small spurs to the east or west, but for the most part showing a smooth side hill lying north and south. The small spurs form valleys or hollows, which are covered with sedimentary rocks.

The first of these hollows (S. ½ of sec. 24) on the east side of the hill is formed by the second ridge, mentioned above, and a mass of blue granite (pulaskite), which forms a small hill about half a mile further south. This hill extends about half a mile to the east of the main ridge and is entirely made up of blue granite (pulaskite). The northern part of the valley is covered by shales of Paleozoic age, and where these occur in contact with the igneous rock, they have been very much metamorphosed.* They present the appearance of close grained, compact igneous rocks, containing spots, in which the texture is almost granitic. These contact specimens and also the eruptive rocks in immediate connection with them, are often highly impregnated with pyrite and are moreover peculiar from the fact that after being broken, they weather very rapidly and become coated with a dark blue or black stain in a few days time. On going farther away from the line of contact, the shaly character of the rock appears more and more distinctly until at some distance, ten to thirty feet (3 to 9 meters), no appreciable metamorphism has taken place. These shales are visible for but a short distance from the igneous rock and are then covered up by Tertiary deposits. Interbedded with the Tertiary rocks, are deposits of bauxite 15 feet (4.6 m), or more, in thickness, and covering a considerable area. These have been briefly mentioned by the State Geologist, in a paper entitled "Bauxite in Arkansas,"† and are more fully described in Vol. I. of the Annual Report of this Survey for 1889. On the south side of this valley conglomerates of quite recent origin occur. They contain much iron and are of a rich brown color. The State Geologist considers them to have been formed during late Tertiary times. They cover up the shales, where they come in contact with them, and form a belt obscuring the contact of the igneous rocks with the latter. There is no evidence of any metamorphic action on these recent deposits, which can be

* The thanks of the Survey are due to ex-Gov. C. C. Bliss and to Mr. George C. Pye for the interest that they have taken in looking up the line of this contact, and in removing the overlying soil, so as to expose the igneous and sedimentary rocks in direct contact.

† Am. Geologist, Vol. VII., 1891, p. 161.

attributed to the igneous rocks, and hence it is quite certain that they are younger than the latter.

Northeast of the end of the granite (syenite) spur forming the above mentioned valley, and situated near the point where the mountain road from the west intersects the turnpike, a small body of syenitic tufa is found, which consists of a rearrangement of detrital syenitic material solidified by a siliceous cement. This material has come from the disintegration of the igneous rocks and is not an original volcanic ash. It is limited in extent and is of comparatively recent origin.

On the south and east sides (S. ½ of sec. 25) of the granite spur forming the above mentioned valley are banks of bauxite, similar in every way to those described above. This bauxite, like that of the other area mentioned, is surrounded by sandy soil and gravel and shows no direct connection with the neighboring rocks.

Starting from the point where the description of the main ridge was interrupted (N. E. ¼ of sec. 26), the ridge extends about two and a half miles (4 km) further in a southwesterly direction, and sends out two spurs to the southeast. A short distance beyond where the ridge turns a slight depression occurs, over which the highway runs, and to the south of this the hill rises to the height of 510 feet (153 m)—its greatest elevation on the east side of the cove—and is known as Ermentraudt Mountain (occupies sec. 34). Taking this point as a center, the hill covers an almost equilateral triangle, two of whose angles lie in the main ridge, and the third forms the spur to the southeast already mentioned. It is between this southeastern spur and that portion of the ridge lying to the northeast, that the most interesting rocks of the region occur. In the flat land, southeast of the point where the ridge turns, both bauxite and sandstones or conglomerates of Tertiary age are found. The bauxite is interbedded with the other rocks in such a way as to indicate that they are all of the same geologic age. Just east of these is a small mass of blue granite (pulaskite), which is bounded on all sides, except where it underlies the sandstone, by loose, yellow, sandy soil and loam, formed by the decay of

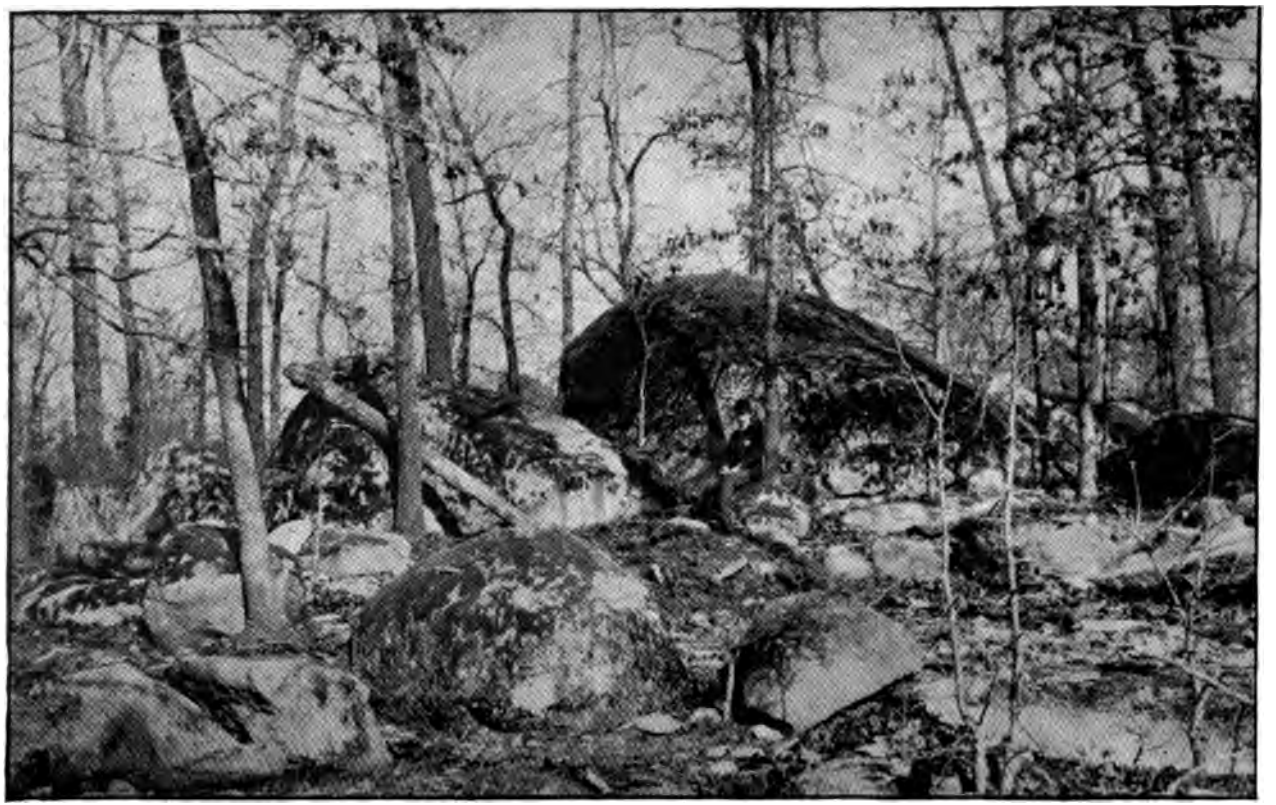
the organic matter in the marshy bottom-land on the southwest. About a quarter of a mile (0.4 km) south of this area, is a small patch of shale, which appears in the highway and indicates that the Paleozoic rocks extend in that direction, although they are, for the most part, concealed by the overlying sand. A mile (1.61 km) to the east of this (N. E. ¼ of sec. 36 and N. W. ¼ of sec. 31), several small patches of blue granite (pulaskite), and one quite large mass of it, occur. The latter is a hard, bluish rock, which, on the north side of the hill, appears decidedly porphyritic in texture. The location and extent of these areas are shown on map II., and as they are bounded on all sides by loose, sandy soil they need no further description.

West of the small patch of Paleozoic rock described above, and lying in the bed of a narrow stream, a small area of gray granite (eleolite syenite)* appears. (S. W. ¼ of N. W. ¼ of sec. 36).

This follows the west bank of the stream for about a thousand feet (300 m) and then disappears. It is covered except on the extreme eastern edge, by loose sandy soil. West of this again about a thousand feet distant, appears a mass of coarse grained syenite (miarolitic eleolite syenite dike rock) which forms a large dike about two hundred feet (61 m) wide in its broadest part, and 1500 feet (456 m) long. It appears as huge boulders, and large weathered masses, which present a most peculiar rounded surface, (see plate 4). On the east of the dike and in its immediate vicinity, nothing but sandy soil is found, and at the point where the Paleozoic rock should appear, if it were present, the soil is so thick that no rock whatever is found. West of the dike the Paleozoic shales are exposed along a belt about a thousand feet wide, extending northward almost to the foot of the mountain, but from which they are separated by a band of sandy soil. A second dike of syenitic rock passes through the western portion of this shale area. It is similar in some respects to the dike just described and parallel to which

* By *eleolite syenite* is understood a rock consisting of eleolite and orthoclase (alkali feldspar), with pyroxene (augite), biotite (mica) and a little amphibole (hornblende). In this rock the eleolite has become an essential constituent instead of remaining subordinate, as it did in the case of the pulaskite.

MIAROLITIC ELEOLITE SYENITE DIKE, SHOWING WEATHERING.



BOULDERS OF BROWN GRANITE. (ELEOLITE SYENITE DIKE ROCK.)

it lies, but differs from it in structure and appearance. It is coarse grained and semi-granitic or trachytic in structure, has a brownish color, and is generally known as "brown granite." It has been quarried to some extent, but the stone has only been obtained from boulders and not from the rock in place. This dike extends in a northeasterly and southwesterly direction, and at its lower end, it makes a slight bend toward the south. In some places the boulders are large and close together, and indicate a dike from fifty to one hundred feet (15 to 30 m) in width, while in other places they are strung along singly, and are far apart, so far in fact, that toward the southern end, it is not an easy matter to trace it at all. (Plate 5). In representing the dike on the map this variation in width has not been taken into consideration, and the dike appears as of almost uniform width. After it leaves the shale which forms the side walls at its northeastern end, it crosses a low, marshy piece of ground, where its course is indicated only by a few scattering blocks, and then crosses the top of a small hill, which appears to consist almost entirely of a black, porphyritic rock (tinguáite) containing large white feldspars, and of a metamorphosed shale.

It is almost impossible to determine the exact limits of this phorphyritic rock, because, on the one hand, it is covered up to a great extent by soil derived from its decomposition, which has gone so far that little or no rock is found *in situ*, and on the other hand, it shades so almost imperceptibly into the metamorphosed shales which surround it, that it is impossible to tell where one begins and the other leaves off.

About a thousand feet (300 m) still further to the northwest is a third dike of rock, similar to that of the last dike described. At both ends it nearly touches the main ridge, and at its central point is not more than three or four hundred feet (ca. 100 m) from its base. All of these belts of boulders have approximately parallel directions, as may be seen by referring to the map, upon which their relative positions are indicated. The space between the innermost dike and the hill is covered with a thick soil, through which are scattered numerous boulders of blue granite (pulaskite).

Beyond this point the main ridge of blue granite (pulaskite) runs southward to the point of the hill which forms the third angle of the triangle, and is bounded by loose sand and bottom-lands. To the south of this ridge, the decomposed granitic rock and soil extend a quarter of a mile or more beyond the foot of the hill and form very fertile and productive land. The rock from which the bottom-land is formed appears to be of the gray variety, but it is so much decomposed that an accurate determination is impossible.

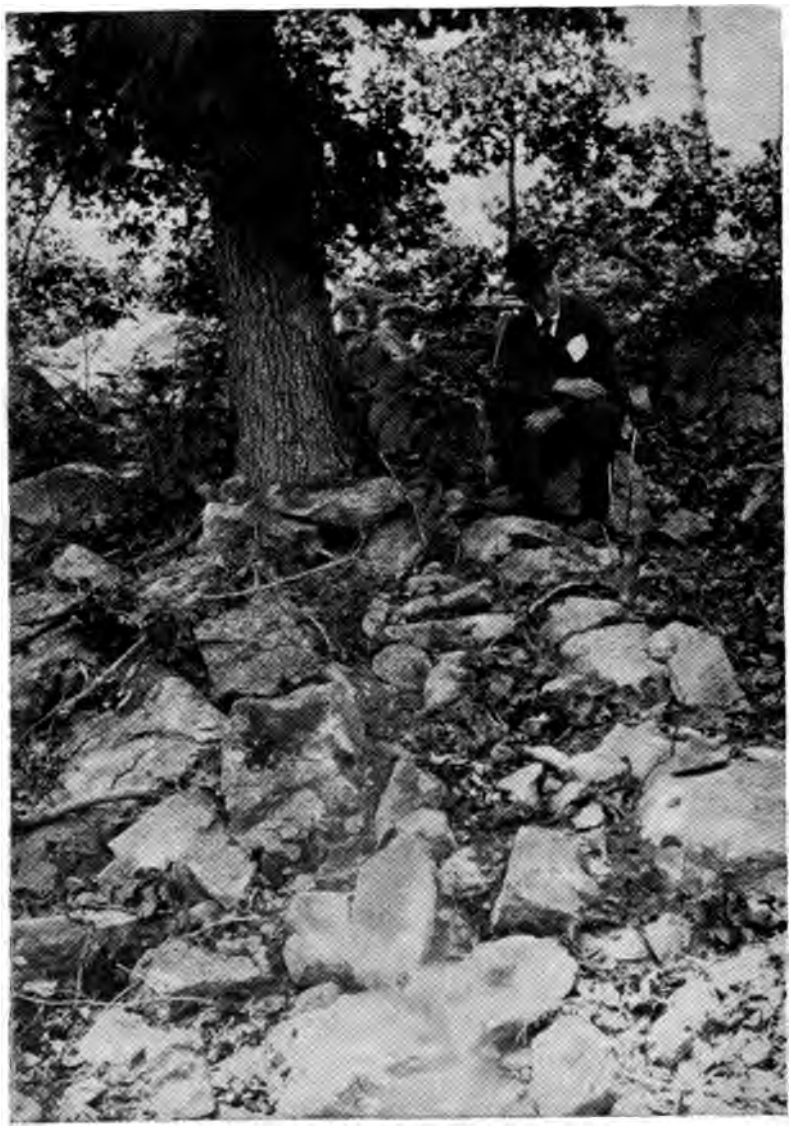
In the highway directly east of the house of Mr. Ermentraudt, a mass of yellowish-brown rock occurs, which shows a decided banding. It has the general appearance of a decomposed gneiss, but it has been shown by a microscopic examination to consist of a mass of syenitic fragments, (orthoclase, basic silicates, etc.,) which have been cemented together by siliceous material, thus forming a sort of tufa. This resembles quite closely that already described (page 23).

The southernmost spur of the Fourche Mountains is named South Mountain (occupies sec. 4) and consists of a mass of blue granite (pulaskite) which runs out in a narrow ridge towards the south. On the east and south the rock is covered by sand and soil, but extends for some distance underneath it into the lowlands. At one point where the granite (syenite) appears about 500 feet (152 m) from the foot of the hill, it consists of a flat mass of gray granite (eleolite syenite).

North of South Mountain a transverse depression separates it from the ridge known as Allis Mountain, (secs. 22, 27, 28 and 33).* This latter extends for about 3 miles (4.83 km) in a north-by-east direction and near its northern end it turns to the northeast and extends for more than a mile in that direction, falling almost exactly into line with Fourche Mountain proper, from which it is separated by the branch of the Fourche Bayou which forms the outlet of the Cove.

Allis Mountain, at its greatest elevation, reaches a height of 520 feet (159 m) above the sea level. As is the case with most of the granite (syenite) ridges, it is comparatively smooth, and

* This is also called Granite Mountain.



WEATHERED BLUE GRANITE (PULASKITE).

is covered with a thick growth consisting mostly of deciduous trees, except where the sides are so steep that they cannot obtain a hold. The side hill is covered with loose blocks of blue granite (pulaskite), among which may be found many ledges of the solid rock. The weathering of this rock into blocks, is very characteristic and plate 6 shows the way in which a side-hill may be covered with them. About the bottom of the hill, and nowhere rising more than forty or fifty feet (12–15 m) from the flat land appears the gray granite (eleolite syenite) in huge flat areas, often two hundred feet (61 m) and more in diameter, and showing hardly a crack or seam in the whole surface. These flat masses appear to occupy most of the area between the foot of the mountain and the Little Fourche, although they are not everywhere visible, because they are often covered over with sand and river mud. These rocks weather in place and form a granitic soil without breaking up into boulders as the blue granite (pulaskite) does. (See plate 7, page 29).

West of the south end of the mountain on the opposite side of the Little Fourche appear banks of bauxite like those described on the east side of the mountain.

At a point a little south of the center of the ridge and on the west side of the mountain the blue granite (pulaskite) appears near the bank of the Little Fourche and is exposed for several hundred feet. It is broken up into the characteristic blocks and shows a decided bluish color.

At only three points has granitic (syenitic) rock been found on the west side of the Little Fourche. In the southernmost of these exposures (west of center of sec. 28) the rock forms the usual flat masses, while in the central one it appears as if it formed a dike, or boss, which has weathered into boulders, in much the same way that the dikes at the southeast of the mountain have done. It is a very coarse grained rock, in which some of the feldspar crystals are as much as eight inches in length. Small fine grained veins containing quartz occur in it in some places, though the most of the rock seems to be comparatively quartzless.

The third exposure of igneous rock on the west bank of the

Little Fourche lies about five hundred feet (152 m) north of the preceding one and consists of a small group of huge boulders, twenty feet (6 m) or more in diameter, and surrounded on all sides by the alluvium of the river bottom. These boulders consist of a coarse grained combination of feldspar, quartz and some altered basic silicate and form, therefore, a quartz syenite dike. Paleozoic rock has been found in a forty foot (12.2 m) well near the first of the dikes mentioned above and lies between the dike and the main mass of the mountain.

The Paleozoic shales appear again on the north side of the Fourche Bayou and form a bluff not more than a mile (1.61 km) northwest of the foot of Allis Mountain. They everywhere dip steeply to the north.

Fourche Cove is an elliptically shaped valley, whose greater axis has a north-northeasterly direction and is about two and a half miles (4 km) in length, while the width of the basin does not exceed a mile and a half (2.4 km). It is enclosed by Fourche, Ermentraudt and Allis Mountains, and its only outlet is at the northern end through the cut occupied by the branch of the Fourche Bayou already mentioned. The cove is drained by a small brook, which has a generally northerly direction, and by small branches, which empty into it from both sides. The total fall from the southern end of the cove to the Fourche Bayou, at the northern extremity, is about one hundred feet (30 m), and as two-thirds of this fall occurs in the first third of the stream's course, the remainder of the way its flow is very sluggish. The bottom through which the stream runs is covered in a great measure with thick underbrush, which has sprung up on the rich alluvial deposits formed by the stream's overflows and by the decomposition of masses of vegetable matter. As would naturally be expected, this bottom-land gives no clue to the character of the rock beneath, and it can only be surmised from the surrounding rocks, that the Paleozoic shales form the floor of the valley below the overlying Tertiary and recent deposits.

On the east side of the cove, just below the blue granite (pulaskite), there are some areas of gray granite (eleolite

FLAT SURFACE OF GRAY GRANITE (ELEOLITE SYENITE).

syenite) which appear as large flat masses and are almost devoid of vegetation. The blue granite (pulaskite) which is found again around these appears to be only in the form of loose boulders. On the west side of Fourche Mountain proper a wide dike of "dike granite" (quartz syenite) occupies the bottom of a narrow valley leading down toward the west. This dike is, in some places, as much as 500 feet (152 m) wide, and forms a straight line from the flat crest of the hill (see page 20), to the cove branch. In many respects it is quite similar to the other dikes observed about the mountain, and is probably directly genetically connected with the one mentioned as lying along the top of Fourche Mountain. A little further south on the same side of the cove is a bed of bauxite, and just above it is a deposit of Tertiary conglomerate or sandstone. These rocks are surrounded on all sides by sand and loose blocks of blue granite (pulaskite). South of this point, two low elevations appear in the center of the cove, and on both of them blue granite (pulaskite) occurs. In some places this rock forms comparatively flat masses like the gray rock, but it still appears to be distinctly of the blue variety. This mass of igneous rock was outlined, as is shown on map II., with as much care as possible, although the thick undergrowth made it almost impossible to obtain its exact boundaries. A little east of this mass of blue granite (pulaskite), on top of the westernmost of the small hills mentioned above, a cap of brown Tertiary sandstone occurs which is completely isolated by sand from all other rock masses.

At the foot of the main ridge, on the east side of the cove, (S. W. of S. W. of sec. 26) large flat masses of the gray rock occur skirting the base of the hill (see plate 7). Near the highway, at the point where it crosses this gray rock, stone has been quarried, so that the weathered surface has been taken off to a depth of three feet or more. The rock here shows a peculiar differentiation into coarser and finer bands, which will be described more in detail later. It is from this quarry that the specimen of the gray granite (eleolite syenite) analyzed was taken (see chapter IV. II. B.b.), but the block for the com-

pression, and other physical tests came from the west side of Allis Mountain, where rock of this nature has lately been quarried by Mr. John S. Braddock. (Chapter IV. II. B. a.)

On the southeast side of the cove the yellow sandy soil which has formed the boundary of the igneous rock along its western edge ceases and the Paleozoic shale appears. In many places this is very much metamorphosed and appears like a hornstone, but a little farther away from the contact the shaly structure is visible.

Near the south end of the Cove loose blocks of a very heavy, black rock appear, which are evidently some form of very basic rock. This has been shown to be olivine-free monchiquite or feldspar-free camptonite, and as it forms a new type it is called fourchite. (See chapter IV. III.) At the southwestern end of the Cove these rocks form almost the whole eastern slope of Allis Mountain and are bounded on the lower or eastern side by the more or less metamorphosed Paleozoic shales, and on the upper edge by the syenitic rock of the mountain. At several places this "trap," as the fourchite is called in the neighborhood, is cut by dikes of coarse grained syenitic rock. The latter are of a light color and resemble to some extent the quartz syenite dikes at other points about the mountain. In some places these coarse grained intrusions form larger masses, as for example, at a point not far south of the mountain road which crosses from east to west over Allis Mountain (center of E. ½ of sec. 32). Boulders of this material are scattered here and there over the depression which forms the top of the mountain north of the above mentioned granitic masses, but the weathering action has gone so far, and the blocks are so few in number that the courses of the dikes cannot be traced.

The trap (fourchite) shows considerable variation in different parts, both in its texture and in its mineralogic constituents, so that petrographically considered it should be classed under several heads.

This mass of trap (fourchite) is a mile (1.6 km) or more in length, and lies in a north-northeast and south-southwest direction, while in width it is not more than one-quarter of a mile

(0.4 km). It is interrupted at a point about a quarter of its length away from the south end, by a valley running to the west and forming a depression in the syenitic ridge (S. ½ of sec. 32). The valley is covered at its eastern end by boggy soil through which no rocks appear, but on its northern side the Paleozoic rocks form a narrow band between the recent deposits and the trap (fourchite). Near the line on the west where the blue granite (pulaskite) crosses this valley, loose boulders of trap (fourchite) appear, which suggest the connection of the larger mass on the north, with the smaller mass on the south side of the valley. At the northern end of the whole trap (fourchite) area the Paleozoic shales again appear, and form the boundary of it.

On the west side of the Cove, in a small valley formed by a spur of the Paleozoic rocks and the main ridge of the mountain, there is much Tertiary rock which is the remains of the layer of Tertiary material which was at one time deposited over the whole Cove and was subsequently carried away by erosion. North of this the Paleozoic rock forms the side hill to a height of about a hundred feet [390 feet (119 m) above mean tide level] above the level of the bottom of the Cove. This rock extends about the base of the mountain to the point where the east and west ridges are separated by the outlet of the Cove.

About half a mile (0.8 km) south of the area covered by the Fourche Mountain group is another mass of syenitic rock which is, however, comparatively limited in its extent. The rock is of the blue variety, and in the largest mass forms a hill 75 feet (23 m) in height [340 feet (104 m) above mean tide level]. It does not cover more than one-quarter of a square mile (65 hectares) in all. The igneous rock is surrounded on all sides by sand, loam, or Tertiary deposits, and in some places fragments of Tertiary sandstone are scattered over the granite (syenite), but it is probable that they are not in their original positions. Deposits of kaolin and bauxite are common in this region, but as the distribution of these substances is more fully described by the State Geologist in Vol. I. of the report for 1889, further mention of their occurrence is omitted.

The granite (syenite) of the region south of Fourche Mountain presents no special features and is very similar to that already mentioned from Fourche Mountain itself. In its color, it is not quite as dark as much of the blue granite (pulaskite) which has been quarried, but this may be due to the fact that only surface rock from this neighborhood has been seen, while the blue granite (pulaskite) of other regions has been worked to a considerable depth and obtained in fresh specimens. At one place, where material for chimneys has been quarried from large boulders, the rock appears to be hard, strong and of good quality.

Taken as a whole, the Fourche Mountain region contains about five square miles (1295 hectares) of surface covered with blue granite (pulaskite), and perhaps one square mile (258 hectares) covered with the gray granite (eleolite syenite), which is either directly exposed or is covered only by a thin layer of soil. These figures do not express the size of the whole area in which the granite (syenite) may be found, but only that in which it is now exposed.

The preceeding description of the topographic features and the distribution of the igneous rock have been given as a matter of course, but all the facts presented there can be obtained much more easily by an inspection of plate 2 (p. 19), which is a reproduction of a photograph of a model * of this region, and by a study of the instrumental contour map (map II.) upon which the geology is completely represented by various colors.

* The thanks of the Survey are due to the Misses Lockwood, of Brooklyn, N. Y., by whom the relief maps of both this and the Magnet Cove region (see chapter VI.) have been carefully prepared.

CHAPTER IV.

MINERALOGIC, PETROGRAPHIC AND CHEMICAL CHARACTERISTICS OF THE ROCK FROM FOURCHE MOUNTAIN.

I. Special Petrographic Literature.
II. Petrographic description of the Syenitic rocks.
  A. Blue Granite (Pulaskite).
    a. Physical Properties.
    b. Crystallographic, Microscopic and Chemical Investigations.
  B. Gray Granite (Eleolite Syenite).
    a. Physical Properties.
    b. Crystallographic, Microscopic and Chemical Investigations.
  C. Dike Rock.
    1. Brown Granite (Eleolite Syenite Dike Rock).
      a. Physical Properties.
      b. Crystallographic, Microscopic and Chemical Investigations.
    2. Miarolitic Dikes.
      a. Miarolitic Eleolite Syenite Dikes.
      b. Miarolitic Quartz Syenite Dikes.
        (1) Coarse-grained Quartz Syenite Dikes.
        (2) Fine-grained Quartz Syenite Dikes.
  D. Porphyritic Border and Dike Rock (Tinguaite).
    a. Occurrence.
    b. Macroscopic and Microscopic Description.
III. Petrographic Description of the Augitic Rocks.
  A. Fourchite.
  B. Amphibole Fourchite.
  C. Monchiquite.
IV. Contact Rocks.
V. Genetic Relations of the Various Kinds of Syenite to each other and to the Adjacent Sedimentary Rocks.

I. SPECIAL PETROGRAPHIC LITERATURE.

Before entering into the detailed description of the rocks of the Fourche Mountain region, it will be well to review more minutely than was possible in the chapter on general literature, the articles which have already been published on this subject.

Bringier.—It appears from what is stated on page 10 that the first mention of this region was probably made by L. Bringier* but if that is the case, he described the rock as a "granite or primitive rock," and of course gave no further notes of it which are of petropraphic interest at the present day.

Powell.—The collection which W. B. Powell presented to the Antiquarian and Natural History Society of Arkansas, in Little Rock,† cannot now be found. Some specimens collected by Powell are, however, in the National Museum at Washington, D. C., and through the kindness and courtesy of Dr. George P. Merrill, the Curator of the National Museum, these were lent to the Arkansas Survey and the writer has thus been enabled to study them in detail, and to see exactly what Powell saw and described. Unfortunately the original labels have been destroyed, so that it was impossible to identify all of Powell's varieties.

Powell calls the principal rock of the ridges (pulaskite) a greenstone, and supposes that the granite (eleolite syenite) underlies it. In speaking of the western mountain he says, "at one point the greenstone and gneiss, except a very small portion of the latter, (and the quantity at first appears to be unusually limited), have been so far denuded as to expose the granite almost to the top of the mountain for half a mile in length. Large areas of it are exposed without a shrub or tree." By the term *greenstone* Powell evidently intends to express the somewhat porphyritic character of the blue granite (pulaskite); and the gneiss, which he mentions, must be considered as a somewhat laminated form of the eleolite syenite.

In describing the rock which he calls granite, Powell writes, "The most of this granite is of the feldspathic variety. In some places blocks of feldspar, of a beautifully foliated structure and

* Am. Jour. Sci., Series 1, Vol. III., 1821, pp. 15-47.

† Geological Report upon Fourche Cove, etc., 1842, pp. 6-11.

shining lustre, six or eight inches long by three wide, are to be seen in the face of the weathered surface. Much of its mica is crystallized in hexaedral prisms; it is without quartz, but its place is apparently occupied by dolomite or magnesian carbonate of lime."

Powell describes a "globular granite," which occurs in a very decomposable granite, as its gangue, and says of it, that the feldspar appears to be in fine grains and arranged in regular forms, and that its faces are covered with copper colored mica of a rich velvet-like lustre. The location which he gives for this on his sketch map would indicate that it occurs at the southeast corner of the mountain, but the writer has not been able to find it in place. He has, however, seen a specimen of it, which was sent by Powell to the National Museum, and finds it to be much as described, although it is so weathered that little can be made out concerning it.

Powell mentions a dark colored granite from the northwestern end of the east mountain, which occurs in several places and is, according to him, the most perfect granite in the region. He states that it contains all the elements of granite, and occasional crystals of tourmaline and sphene. He adds that it is very tough and hard, and appears from its position to be younger than the other formations.

Near this he found a line of "lozen or bisquit shaped masses" of hornblende granite * extending for half a mile or more. In a footnote he states that this, like many of the others, is a quartzless variety of granite. He mentions the fact that this same rock appears in the midst of the "hornblende rocks" (fourchite), and that a dike of it six inches wide is seen cutting them. Also that it appears in the flat at the top of the west mountain between the granite and the "hornblende rocks."

Powell states it as his opinion that the greenstones (pulaskite) were formed immediately after the granites (eleolite syenite), because one passes imperceptibly into the other. Of the greenstones (pulaskite) he says, "They are generally highly

* Quartz syenite.

crystalline in their structure, so much so as to merit the appellation of syenitic or trachytic."

Under the name *cornean*, which he takes from De la Beche's geology of Pembrokeshire, but by which, he states, he does not wish to suggest any relation or similarity between the rocks that he describes and those of that author, Powell describes what he considers to be the intermediate stages in the transition of the greenstones into basalt. He adds that some of them are partly stratified, while others are almost perfect hornstones. He divides them into quartzose, feldspathic and hornblendic corneans, and says that they both precede and follow the basalts, but that those which follow are the more imperfect, and are finally lost in claystone. This gradual transition, he states, does not take place inside of the Cove but on the eastern side of the east mountain. He gives, however, as a locality for corneans of various kinds a point not far from the base of the east mountain on the inside of the Cove. It seems probable from Powell's description that he includes under this name the metamorphosed and hardened shales found inside the Cove, and the porphyries and metamorphosed rocks found at the southeast corner of the region (see page 25). At the point where the great mass of basaltic rock occurs at the south end of the Cove, Powell found no such transitions, but states that the basalt (fourchite) is superimposed upon the greenstone (pulaskite), and abuts against it. He mentions several varieties of basalt (fourchite), which he considers local variations of one and the same rock. He describes a smooth, dense, greenish rock as one limit, and the coarse-grained hornblende rock as the other, and states that they are both basaltic in their characteristics. After these rocks he describes kaolin and bauxite, without discovering the true nature of the latter, but says nothing more about the crystalline rocks.

Owen.—D. D. Owen, in his report,* describes granite from the northwest side of Allis Mountain (E. ½ of N. E. ¼ of sec. 28, 1 N., 12 W.) as follows: "This granite is eminently feldspathic, the feldspar containing both soda and potash, though it has the white color, lustre and cleavage of cleavlandite. The quartz is

* Second Report of a Geological Reconnoissance of Arkansas, 1860, p. 69.

pale gray; a few crystals of hornblende are disseminated with occasional flakes of black mica. This rock might perhaps be called a granite-syenite, but the proportion of hornblende and mica is so small that it is better designated as a feldspathic granite."

The basaltic rock on the west mountain is described as a "very ponderous, black, porphyritic basalt, composed chiefly of augite, with large interbedded crystals of jet-black augite." Owen describes also a compact basalt from the same region. On the southeast slope of the Ermentraudt Mountain the rock is described as being more porphyritic in character and as containing more black mica.

Shepard.—C. U. Shepard published in the article already quoted* a list of rocks from Arkansas, which were sent to him by the Rev. E. R. Beadle of New Orleans. Among them were two specimens from Fourche Cove. They are described as follows:—

a. "Gray granite (without quartz) with black mica in small scales, imparting to the rock the aspect of a sienite. It contains everywhere diffused through its mass minute hyacinth-red crystals,† having the hardness of monazite. From Fourche Cove, Pulaski County. Sec. 34, 1 N., 12 W."

b. "From same place (Sec. 33, 1 N., 12 W.) a coarse amygdaloidal basalt, containing thickly implanted crystals of grayish black pyroxene, above an inch in length and much resembling those found at Aussig in Bohemia."

Harvey.—F. L. Harvey in his "Minerals and Rocks of Arkansas," describes the following rocks from Fourche Cove. He says (page 31): —

"Granite.—Composed of quartz, feldspar and mica. These ingredients differ in relative quantity, color and size of the crystals, giving a great number of varieties. Typical granite occurs in Fourche Cove, Saline county and Magnet Cove. The following varieties are also found in Arkansas. *Hornblendic*

* Am. Jour. Sci., Series 2, Vol. VII., 1846, p. 253 (foot note).

† These are probably some of the red colored titanite crystals which occur in such large numbers in this rock.

Granite, having a small quantity of hornblende with quartz, feldspar, and mica occur in Fourche Cove. Might be called *granitic-syenite*."

"Porphyritic Granite.—Porphyry is any fine-grained feldspathic rock containing large crystals of feldspar. Occurs in Saline county, Fourche Cove, Magnet Cove and Pike county."

"Feldspathic Granite.—Contains a preponderance of feldspar and occurs at Fourche Cove, Pulaski county. This has been used to make an inferior millstone."

"Trachyte.—A rock consisting mainly of feldspar, and containing crystals. Breaks with a rough fracture. Gray Trachyte occurs in Fourche Cove, and from the weathering of it kaolin beds have been formed."

"Hornblende Rock.—* * * There is at Fourche Cove a grayish rock, composed of Augite and Labrador feldspar."

"Doleryte (Trap. Basalt).—Basalt occurs at Fourche Cove as a compact, close-grained augitic rock, porphyritic basalt and ferruginous trap."

He closes his paper by saying, "The syenitic-granites of central Arkansas are fined grained; even in texture, contain but little mica and hornblende, and rather too much feldspar. They, however, make a good stone for bridge work and buildings. Vast quantities of good granite occur in Fourche Cove, Saline county, and Magnet Cove."

Comstock.—T. B. Comstock, in the report of the Geological Survey of Arkansas, refers to the present report for a full description of the igneous rocks, but mentions (page 11) the occurrence of two varieties of porphyritic rock, viz.: "Porphyry, basic (iron-bearing minerals), basaltic thinning northeast. Porphyry (siliceous) felsitic, etc., thinning southwest." He also mentions "massive igneous rocks" as forming the main portion of the ridge of Fourche Mountain.

Day.—David T. Day in the Mineral Resources of the United States for 1888 (loc. cit. p. 537) writes as follows regarding the Fourche Mountain syenite: "The granite is properly a syenite, and is known as the Fourche Mountain granite of Arkansas. The following is an analysis of this

granite made under the direction of Dr. John C. Branner, State Geologist *: —

Analysis of Fourche Mountain granite, Arkansas.

Silica	60.03
Ferric oxide	4.01
Ferrous oxide	0.75
Alumina	20.76
Lime	2.62
Magnesia	0.80
Phosphoric acid	0.07
Potash	5.48
Soda	5.96
Manganese	Trace
Water at 110°-115° C	0.06
Loss on ignition	0.53
Total	101.07

"This granite is well adapted not only for building stone, but more especially for monumental work. Although the operations of this company (Arkansas Granite Company) are of such recent date, the amount of business already done by it is quite considerable. It was awarded the contracts for furnishing paving blocks to the cities of Memphis and Louisville for the year 1889."

II. PETROGRAPHIC DESCRIPTION OF THE SYENITIC ROCKS.

A. Blue Granite (Pulaskite).

As may be seen from the preceeding chapter the main ridges of the Fourche Mountain region are made up of the so-called "Blue Granite," the stone most used as a building and paving stone.

a. Physical Properties.

Structure.—When macroscopically examined, the first thing which strikes the eye is the peculiar semi-porphyritic appearance of the rock. The feldspar crystals stand out conspicuously on account of their highly perfect cleavage-planes and the light reflected from them. When they have

* R. N. Brackett, analyst.

any distinct crystal form, they appear, for the most part, to be tabular parallel to the clinopinacoid (010), and to give a general trachytoidal appearance to the rock. The crystals are not usually sharply defined, but show a rough surface, due to the early formation of crystals of a second generation. Occasionally a flake of dark mica or portion of a crystal of hornblende or augite is visible, but in general the basic silicates are not conspicuous. In the spaces not occupied by the large feldspars, a mass of finer grained material appears, which shows minute reflecting surfaces, indicating that it is made up of small feldspars of a second generation. See plate 1 (frontispiece).

Color.—The color varies between wide limits, in some cases being a dark bluish-gray, while in other localities the rock is light gray (not the "gray granite"), but still retains something of the bluish tinge. The color depends upon that of the feldspar, and is not due, as might be supposed to an admixture of dark colored minerals in varying proportions.

Jointing.—The fact that the sides of the mountain are covered with comparatively small blocks of this rock, and that ledges appear only occasionally, and then generally near the tops of the ridges, indicates that the rock on weathering has broken up into sharp cornered blocks which even after long exposure still retain their angular form. These have rolled down the sides of the hill and compose the extensive talus, which is so characteristic of these ridges (plate 5). As would be expected from this easy separation into blocks the surface rock is usually found to be unsound for some distance down, so that where such surface material is used great care must be exercised in selecting blocks for dimension work. As the quarries are pushed deeper into the hill, the stone becomes more solid, and by the time that a considerable depth has been reached, the material is found to be satisfactory for large dimension stones. (See plate 7 showing stone quarried from the Fourche Mountain granite quarry).

Hardness.—By hardness is to be understood not the

strength as determined by compression, but the resistance to wear. This is a subject to which very little attention has been paid, and one upon which it is very hard to obtain any data. The writer has endeavored to obtain some facts which might be used as a basis for comparison, and to this end letters, in which were enclosed a list of questions, were sent to many prominent granite quarries in the country.

It was thought, that in order to arrive at numerically comparable results, the following points should be taken into consideration, and that they would give some idea as to relative resistance to abrasion or *the hardness* of the rock. These considerations are as follows: —

1st. The rate of penetration of a drill of given diameter.

2d. The distance to which such a drill will penetrate without being sharpened.

3d. The amount of surface of stone, which can be dressed down from a rough pointed to a bush-hammered surface in a given space of time.

4th. The depth to which a sand wheel will cut away a square foot of surface in a given time.

There are, however, many secondary considerations which should be taken into account in comparing such facts, but for which no standard of comparison can be obtained. Thus, for example, the nationality of the turners and strikers, the portion of the country in which the quarry is located, and the conditions under which the men work, have great influence upon the distance penetrated per hour by the drills. The quality of the steel in the drill used and the degree of temper are important points in regard to the distance penetrated before sharpening is required. The amount of stone cut away with a bush-hammer or peen-hammer in a given time, is perhaps more than all the others, dependent upon the skill and diligence of the workman.

On account of the various kinds of abrasive materials used at the present time to replace sand no satisfactory results could be obtained regarding the rate of cutting of a sand wheel. In some cases Tilghman's chilled shot is used, while

other granite workers employ the Pittsburgh Crushed Steel Company's patent crushed steel.

Thus it appears that although no very sharp distinctions can be anticipated, it may be possible to draw some conclusions regarding relative hardness, which are of interest. The deductions drawn from the answers sent by the various granite firms who have seen fit to reply to the questions sent to them, and whose answers were of such a character that they could be made comparable with the others are given in tabular form on page 43.

From this tabulation it will be seen that the blue granite from Fourche Mountain is in general harder than most true granites from other parts of the country. This is due to its compactness and to its almost complete lack of porosity, as shown by its low degree of absorptiveness. Although the hardness of quartz (7), which is a constant constituent of all true granites, is greater than that of feldspar (6), it is at the same time more brittle, and is consequently chipped away more rapidly by the pounding of the drill. The mineral eleolite is somewhat softer than the feldspar, so that in rocks in which the former is present in large quantities, the hardness is less than in those where it is wanting. The syenite of the Diamond Jo quarry at Magnet Cove, Arkansas contains large quantities of eleolite and is consequently not as hard as the blue granite (pulaskite) of Fourche Mountain.

Strength.—The strength or resistance to crushing of the blue granite (pulaskite) is very great, and as is shown by the tests given below it is considerably stronger than any true granite yet tested. In order to prove this a number of compression tests were made upon blocks cut from blue granite (pulaskite) of various shades of color. These blocks were so cut as to give as nearly as possible one and a half square inches of bearing surface. In order to reduce as much as possible the effect of the jar of dressing upon the rock, the blocks were sawed from hammer-broken specimens three inches or more on an edge. They were sand-rubbed on all sides, but not polished. Before being broken, they were measured on a

Table of relative hardness.

LOCATION OF QUARRY.	ARKANSAS. Pulaski County.	ARKANSAS. Saline County.	ARKANSAS. Magnet Cove.	Ortonville, Minn.	Millford, Mass.	St. George, N. B.	Quincy, Mass.	Aberdeen, Scotland.	Quincy, Mass.
NAME OR OWNER OF QUARRY	Fourche Mt.	Nethercutt.	Diamond Jo.	Jos. Baxter.	Timothy Shea.	Bay of Fundy Red Granite Comp'y.	Clencoe Company.	Stirling Hill.	Craig & Richards.
KIND OF STONE.	Pulaskite.	Eleolite Syenite.	Eleolite Syenite.	Granitoid Gneiss.	Granite.	Granite.	Granite.	Granite.	Granite.
Strength on Compression, pounds per square inch	30740	.....	.....	.....	11580	14000	.....	21509	.....
Weight per Cubic Foot	166½	162⅓	.....	170	180	168	160	160	165
Inches per hour penetrated by 1¼ inch drill—two strikers	7	15	18	9	12	12	24	24	30
Inches penetrated before sharpening is required	4	10	9	6	6	6-9	6	12	8-12
Number of square inches which can be dressed down from a rough pointed to a finished surface, per hour	144	.....	72	72	86	144	72	.....	72-96
Fraction of inch, per hour, which a grinding table cuts away from a surface one square foot in area	.....	.....	.....	¼	.....	¼	¼	.....	?
Abrasive materials used	.....	.....	.....	Crushed steel.	.....	Chilled shot.	.....	.....	Chilled shot.

micrometer and were carefully examined to be sure that no flaws or cracks existed, which might influence the results.

The blocks were bedded upon book-binders' board in order to give a good bearing surface and to equalize the pressure. *

The tests were made upon a 50,000 pound (Tinius Olsen) testing machine at the Rensselaer Polytechnic Institute in Troy, New York; the machine was kindly loaned for the purpose by P. C. Ricketts, C. E., Professor of Rational and Technical Mechanics at that institution.

The following list is arranged according to the color of the specimens tested; the lightest coming first and the darker varieties following in their order. †

Table of Compression Tests of "Blue Granite."

	Color.	Area of Surface in square inches.	Actual crushing load in lbs.	Pressure in lbs. per square inch.	Reduced to correspond to pressure per sq. in. on 2 in. cubes (‡) in lbs. per square inch.
1	Light blue.....	1.64	47,000	28,700	33,280
2	Slightly darker....	1.07	22.800	21,500	26,820
3	Slightly darker....	1.57	35,950	22,900	26,745
4	Medium blue.....	1.50	43,500	29,000	34,950
5	Very dark blue.....	1.57	44,900	27,900	32,630
	Mean.....	.....	.....	26,000	30,960

These blocks all broke without cracking. They exploded with great force, and those which stood the highest pressure tore the book-binders' board completely to pieces when they broke,

* For the use of this material see "Tests of Rutland and Washington County Slates" by J. Francis Williams, Van Nostrand's Eng. Mag., No. CLXXXVIII., New York, 1884, pp 101-103.

† This list, including several other rocks to be mentioned later, was published in the Railroad and Engineering Journal, Vol. LXV., 1891, p. 13, under the title of "Tests of Some Arkansas Syenites."

‡ Q. A. Gillmore in his report on Compressive Strength, etc., of building stones of the U. S. Appendix II., of annual report of Chief of Engineers for 1875, Washington, 1875, states that the resistance to compression per square inch of bed surface in cubes of different dimensions varies as the half-ordinates of a cubic parabola.

The reduction, therefore, may be accomplished by applying the formula $y = \sqrt[3]{zp}$, where:

y=pressure per square inch in block of required size.

z=length of edge of block required in terms of edge of block tested.

p=crushing strength expressed in pounds per square inch, as obtained from the block tested.

showing with what great velocity the particles of the stone were forced apart.

The specimens tested had approximately the size and appearance shown in the accompanying cuts. The blocks are drawn in oblique projection.

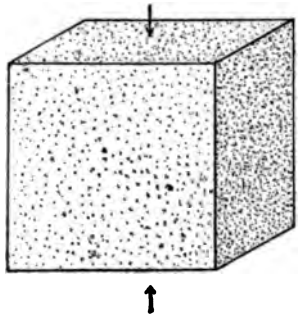


Fig. 1.
Cube of blue granite (pulaskite) prepared for crushing. Scale 9:10.

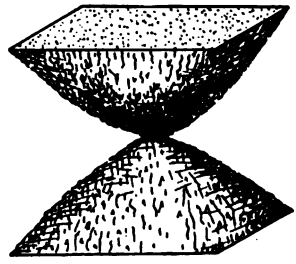


Fig. 2.
Cube after being crushed.
Scale 9:10

After the crushing two paraboloids (?), similar to those shown in Fig. 2, usually remained point to point as indicated, and the material which made up the rest of the block was generally reduced to powder, or broken into thin splinters and wedges.

The specimens from which these blocks were cut were taken from the various quarries on Fourche Mountain, but as some of the pieces were more weathered than others, and as some were subjected to more jar in preparing them than the rest were, it seems best not to indicate the exact localities where the several specimens were obtained, lest such a statement should lead to unwarranted discriminations.

It will be seen by comparing the results of these experiments with those obtained by Gillmore (loc. cit.), that the compressive strengths are much higher than those of any of the granites given in his table. A list of some of the more important granites of the country, as taken from Gillmore's report, is given below. It shows that the Fourche Mountain blue granite (pulaskite) is much superior to any of them in strength.

Compression tests of Syenite and Granite.

LOCALITY.	Pounds per square inch in two-inch cubes.
Fourche Mountain, Ark. (highest test)	34,150
Fourche Mountain, Ark. (mean of 5 tests)	30,740
St. Cloud, Minn. (highest test)	28,000*
Pompton, N. J	24,040
Mystic River, Conn	22,250
Staten Island, N. Y	22,250
Maine (highest in state)	22,125
Richmond, Va	21,250
Huron Island, Mich	18,125
Westerly, R. I	17,750
Quincy, Mass	17,750
St. Cloud, Minn	17,000
Bay of Fundy, Canada	12,020
Average of 82 tests	15,700

In the case of dimension stones it is seldom that a crushing strength of over 15,000 pounds per square inch is required.† Builders seldom place a stone where it will be obliged to stand a pressure of more than one tenth of that which it stoodat its test, and as the maximum pressure at the base of the Washington monument‡ is but 25.377 tons (of 2,000 lbs.) per square foot, or 342.4 lbs. per square inch, this is by no means a difficult matter, as almost any compact stone, no matter of what material, will stand over 3,000 lbs. pressure per square inch. In the case of arches, where the pressure in the ring-stones is very great these are often cracked and it is probable that the great pressure com-

* The test of the St. Cloud. Minn., gray hornblendic granite (syenite of Winchell) is taken from "Geology of Minnesota, Vol. I. of Final Report, Chapter III. Building Stones of Minnesota, by N. H. Winchell, Minneapolis, Minn., 1884," pp. 196-197.

† "Building Stone in New York" by John C. Smock: Bulletin of New York State Museum, Albany, 1890, p. 355; also G. P. Merrill: Report, Smithsonian Institution, 1885-1886, Part II., p. 490.

‡ Tenth Census of the U. S., Vol. X., p. 359.

bined with an unequal distribution over the surface accounts for it. In large buildings single columns and blocks of stone are often required to carry huge masses of superstructure. Single blocks of stone are used in supporting the ends of bridge trusses and girders, where the pressure is undistributed. In such cases and for such purposes as these no better stone can be desired than the Fourche Mountain granite.

Absorptiveness.—By absorptiveness is understood the capacity of the stone to take up or absorb water. N. H. Winchell in his report on the building stone of Minnesota (loc. cit., pp. 185–186) minutely describes a method for determining the absorption of water from the air, and another similar one for the absorption of water, when the stone is immersed in it. In the case of the blue granite, the amount of water absorbed by the immersed stone was so small that it was evident that there would be no use of making tests upon the absorptiveness in air. The method of determination here adopted is virtually that described by Winchell, but which was first suggested by Gillmore in his report on building stone (loc. cit., p. 8). The process may be described as follows:—

A piece of rock weighing from 30 to 60 grams (ca. 1 to 2 ounces), which has been rounded and smoothed until no sharp corners nor deep depressions remain; in fact until it becomes what is generally designated as "waterworn," was weighed in the air. It was next immersed in water and allowed to remain twenty-four hours and was then removed, dried externally with a piece of filter paper and weighed again. It was then again immersed and after another day reweighed, and in case the difference between the two weights was not very great,* this second weight was taken as that of the stone saturated with water.

The absorptiveness is expressed in figures, by giving the number of parts by weight of stone, which are required to absorb one part by weight of water. This is called the *ratio of absorption*, and is as follows for the blue granite (pulaskite), from Fourche mountain and for several true granites from other places.

* If the difference was large the stone was again immersed and weighed again after another day, and so on until an approximately constant weight was obtained.

Table of absorptiveness.

LOCALITY AND VARIETY.	RATIO OF ABSORPTION.
Fourche Mountain, Ark., (Medium "blue granite")	1 to 1673
Fourche Mountain, Ark., (Dark "blue granite")	1 to 4530
St. Cloud, Minn., (red)	1 to 212
St. Cloud, Minn., (gray)	Traces (prob. not better than 1 to 500).
Richmond, Va.	1 to 848
Niantic, Conn.	1 to 704
Staten Island, N. Y. Westerly, R. I. Quincy, Mass. Fox Island, Me.	In all of these the absorption is stated to be too small to be observed while weighing (Gillmore). It is probable that none of them would on soaking absorb less than 1 to 2 or 3 thousand (J. F. W.)

From the above it will be seen that the absorptiveness has been determined for very few of the important rocks of the country and for the most part only for those whose ratio of absorption is comparatively large.

If the Fourche Mountain blue granite had been determined in the the same way that the others were (i. e., only allowing them to soak a few minutes) the absorption of water would have been absolutely imperceptible. Of the two rocks from Fourche Mountain, the darker one is evidently the less absorptive, for it takes 4530 parts of it by weight to absorb one part of water, while in the case of the lighter rock only 1673 parts are required to absorb one part of water. Either of these ratios indicates a rock, which is exceedingly impervious to water, and one in which the interstitial spaces are very small. It is consequently a rock which will stand well in a moist climate, where great changes of temperature are frequent. In this connection it may be stated, that much of the disintegration of rock is due to the alternate freezing and thawing of the water contained in the pores of the rock.*

* "Report on Building Stones," 1868, by James Hall. Reprinted in 39th annual report of New York State Museum, Albany, N. Y., 1886, pp. 36 and 37. Since this article was first published in 1868 by Prof. Hall, many writers have mentioned this subject, thus T. Sterry Hunt states: "Other things be ng equal, it may probably be said that the value of a stone for building purposes is inversely as its porosity or absorbing power," Chemical and Geological Essays by T. S. Hunt, Boston, Mass., 1876, p. 164. Among the other articles upon this subject, the following may be mentioned as being among the more important:

"Decay of the Building Stones of New York City" by Alex. A. Julien; Transactions of N. Y. Academy of Sciences, 1873, p. 67.

Building Stone in New York, by John C. Smock; Bulletin of the New York State Museum, Vol. II, No. 10., Albany, 1890, p. 373.

Some experiments* have been made upon true granites with a view to determining practically the amount of action which freezing has upon the rock, but in no case have the experiments been carried on long enough to admit of any general deductions being drawn, further than to observe, that in a general way a disintegrating action takes place.

Almost all authors seem agreed upon the fact that in porous, coarse-grained granites with large interstitial spaces, the action of frost is greater than in fine-grained, compact rocks.†

Specific gravity and weight per cubic foot.—One of the most important matters in connection with the usefulness of a building stone, is its weight per unit of volume. This is expressed scientifically by means of its specific gravity, that is, the weight of any volume of it whatever, when compared with the weight of an *equal volume* of water at 60° F. (15.5° C.), taken as a unit. For practical purposes the absolute weight of a cubic foot of stone, expressed in pounds is more convenient. The weight per cubic foot may be obtained approximately from the specific gravity, by multiplying the latter by $62\frac{1}{2}$, the weight in pounds of a cubic foot of water at 60° F. (15.5° C.).

Another common expression for the weight of stone, is the number of cubic feet contained in a ton (2000 lbs.) and is obtained by dividing the number 2000 by the weight of a cubic foot of stone expressed in pounds. In the following list are tabulated the strength per square inch in two inch cubes, specific gravity, weight per cubic foot, and number of cubic feet in a ton of three shades of the "blue granite" from Fourche Mountain and of granites from other localities, chosen on account of the extremes in weight and strength which they show.

* N. H. Winchell. loc. cit., p. 186. Experiments by J. A. Dodge of the University of Minnesota.

† N. H. Winchell (loc. cit., p. 188) makes two statements in regard to this matter, which at first sight seem somewhat contradictory. He writes, "A stone that *absorbs moisture* abundantly and rapidly is apt to be injured by alternate freezing and thawing." And in the next paragraph he states, "A stone that is *compactly* and *finely* granular will exfoliate by freezing and thawing more easily than one that is coarse-grained." In the latter statement he evidently refers to the clayey, close-grained, granular rocks as distinguished from the crystalline and fibrous rocks, since in the next sentence he states that the former disintegrate much more rapidly than the latter.

Table showing relation of weight to strength in granites.

LOCALITY.	COLOR.	Strength per square inch in 2 inch cubes.	Specific gravity.	Weight per cubic ft. expressed in lbs.	Cubic feet per ton (2000 lbs).
Fourche Mountain, Ark.	Light blue	33,280	2.635	164.7	12.14
" " "	Medium blue	34,950	2.642	165.1	12.11
" " "	Dark blue	32,630	2.690	168.1	11.89
" " " (Average)		33,620	2.656	166.0*	12.05
Staten Island, N. Y.	Blue	22,250	2.861	178.8	11.18
Jersey Heights, N. J.	Very dark	22,250	3.030	189.5	10.55
Dix Island, Me.		15,000	2.635	166.5	12.01
Quincy, Mass.	Light	14,750	2.695	168.7	11.91
Westerly, R. I.		17,750	2.646	165.6	12.07
Carver's Quarry, Me.	Light	15,093	2.575	161.0	12.42
New Haven, Conn.	Gray	9,500	2.600	162.5	12.30

It will be observed that, where granites having about the same weight as the Fourche Mountain rock are considered, they have very much less strength, and where the strength approaches that of the Fourche Mountain rock, they increase very much in weight.

Effect of heat.—Specimens of blue granite (pulaskite) were experimented upon with regard to the effect of heat only in a very crude way. The various specimens were successively placed in a crucible and brought to a red heat in a crucible furnace heated by gas, and the following effects were observed:

a. Up to the point where the first degree of redness was observed, no alteration in the stone was detected.

b. Up to a low red heat, the stone was only slightly and superficially injured. When rubbed in the hands after having been so heated small particles of feldspar were detached.

c. Up to a bright red heat, the stone showed the same deterioration as mentioned above, but in a greater degree, and in addition it emitted a rasping, hollow sound, when rubbed in the hands, showing that to a considerable distance below the

* Average weight per cubic meter of the blue granite is 2659 kilos.

surface the feldspar crystals had become cracked and separated. No cracks were observed in the stone itself.

It is probable that the stone stood these rather severe tests as well, if not better, than specimens of true granite, that is granite containing quartz, would have stood them.

The most complete paper upon the subject of the effect of heat upon granite is that published by H. A. Cutting. *

Cutting says: "When the specimens were heated to 600 degrees Fah., I have immersed them in water, also immersing others, or the same if uninjured, at varying temperatures up to 800 and 900 degrees, that is, if they are not spoiled at less temperatures."

On page 4 he remarks: "I find that all these samples of building stones (granites, sandstones and limestones) have stood heat without damage up to 500 degress. At 600 degrees a few are injured; but the injury in many cases commences at or near that point. When cooled without immersion they appear to be injured less, but are ready to crumble, and I think they are many times nearly as much impaired, and always somewhat injured where water produces any injury."

N. H. Winchell in his work on the building stones of Minnesota, already cited, gives numerous experiments on the heating of granites and other stones (loc. cit., p. 186).

Recapitulation of results.—A recapitulation of the results of the foregoing tests may be given in a few words, which will show very decidedly the great value of the Fourche Mountain granite (pulaskite) as a building and paving material.

1. Its strength is greater than that of any known granite.
2. Its hardness, or resistance to wear is very great, and as far as comparison has been possible, it has been shown to be harder than any true granite.
3. Its weight is less than that of most true granites, and when compared with that of granite having at the same time great strength, it is found to be less than that of the latter.

* Notes on Building Stones, also on Plant Growth, by Hiram A. Cutting, A. M., Ph. D., State Geologist, Vermont, Montpelier Vt., 1880. This was also published in the state report of Vermont.

4. Its resistance to fire is considerable and is probably greater than that of any stone containing quartz.
5. Its porosity and absorptiveness are very small, and amount to practically nothing. Hence the action of frost and moisture upon it will be reduced to a minimum.
6. On account of its lack of porosity, and the uniformity of its mineralogic composition, the action of acids and corrosive gases upon it is very slight.
7. Its resistance to weathering, which is in a great part determined by Nos. 2, 5 and 6, is probably very great, and indeed it is actually shown to be so, by the sharp corners and sound faces of the rock, which for centuries has lain on the side of the mountain, exposed to the action of the elements.
8. Its color is extremely pleasing, and as the amount of iron compounds present is very small the stone does not easily stain or change color. It is probable, however, that in time the dark bluish gray color will become somewhat lighter, owing to the fading out of the blue-gray feldspars.
9. Its hardness makes the drilling, quarrying and the dressing of the stone somewhat more difficult than is the case with true granites, but this is offset, in a great measure, by the natural planes of separation, which are found lying at nearly right angles to each other in the massive rock, and which are so distributed as to facilitate the quarrying of the rock in a very marked degree. (See plate 3, p. 20).

N. H. Winchell (loc. cit., p. 199) prints a table in which he gives "credits" on a basis of ten for each one of the qualities of a rock and obtains the list given in the first column of the following table for the granite from East St. Cloud, Minn.* The second column of the following table contains the results of the tests on the blue granite (pulaskite) from Fourche Mountain.

* The quality *hardness* was not considered by Winchell, but has been inserted in the table, which is in other respects (total and average excepted) as he gives it.

Table showing relative qualities of Arkansas and Minnesota "Granites."

TESTS.	E. St. Cloud, Minnesota granite.	Fourche Mountain, Ark., blue granite (pukite).
Crushing strength (bedded)	10	No bedding.
Crushing strength (on edge)	10	11†
Ratio of absorption	10	11
Absorption of moisture in 7 weeks	10	...
Absorption of water in 4 days	8	10
Frost 8 weeks, visible effects	10	...
Loss of weight by frost	10	...
Visible effects of dry heat to redness	10	10
Visible effects of water on dry stone	5	...
Effect of carbonic acid in 6 weeks	10	...
Visible effects of corroding vapors	9	...
Loss of weight by corroding vapors	10	...
Facility of dressing	5	3
Hardness	7*	10
Total credits	124	55
Rank on scale of 100	**88.5**	**91.1**
Color	Gray.	Blue.

By this rating, the strength and absorptiveness of the Arkansas rock become more than ten. That the Little Rock granite stands below that from Minnesota in "facility of dressing" may be assumed from the statistics received from the Ortonville, Minnesota, quarries, the stone from which is probably very similar in character to that from E. St. Cloud.

The low rank of the Fourche Mountain rock in "facility of dressing" is offset by its superior "hardness," for as was shown above, these two properties are almost complementary.

Prof. Winchell states that as far as the true relative values of rocks for practical purposes are concerned some of the tests are much more important than the others. Thus the resistance to fire and the absorption of moisture from the air are less im-

* Not given in Winchell's table.

† Although not mathematically allowable, this representing of certain qualities of the Arkansas rock by numbers greater than 10 gives a better idea of the relative value of the two rocks than could otherwise be obtained.

portant than the strength, hardness and resistance to frost action. It would, however, be very difficult to construct a table or ratio which would express these relative values correctly.

Uses of blue granite.—The blue granite (pulaskite) has already been quarried to a considerable extent both as a building stone* and as a material for roads, either in the form of Belgian blocks for streets or of crushed stone for macadamized highways. As a building stone it has been used very largely in the form of window- and door-sills, window-caps, water-tables, stone steps, and foundation materials, and has also been used as the principal wall stone in several large edifices.

The Pulaski county court-house (plate 9) on the corner of Second and Spring Streets, Little Rock, is built above the basement of blue granite (pulaskite) trimmed with limestone. The basement is constructed of the brown granite (dike rock), and will be mentioned later. This building is tasteful and the contrast between the different stones used in its construction is very pleasing.

The Roman Catholic cathedral on the corner of Seventh and Louisiana streets, Little Rock, is built partly of the blue and partly of the brown granite, but the two stones are mingled in such a way, as to give a somewhat mottled appearance to the building. It is, therefore, not as handsome a building as would have been produced had either rock been used alone.

The Dallas County court-house in Dallas, Texas, is built in part of the blue granite of Arkansas and is already so far completed as to show that it will be an extremely handsome building. Several other buildings in Dallas are built in part of the Arkansas stone.

The First Methodist Church of Memphis, Tennessee, is built mostly of the blue granite, and this material has been extensively used in the construction of a large brewery in the same city.

The stone appears in many store fronts, retaining walls, bridge piers and abutments throughout the state, and has also

* Plate 8 shows a number of blocks of blue granite dressed at the "Fourche Mountain quarry" owned by ex-Governor C. C. Bliss of Little Rock.

DRESSING BLUE GRANITE (PULASKITE). "FOURCHE MOUNTAIN" GRANITE QUARRY.

[PULASKI COUNTY COURT HOUSE. BUILT OF BLUE GRANITE (PULASKITE).

been much used for such minor purposes as hitching and gate posts and mounting blocks.

Thousands of tons of this rock have been quarried for Belgian blocks, and have been shipped to many of the neighboring cities, as Louisville, Memphis, etc., as well as having been used in Little Rock itself. No better stone can be conceived of for this purpose, for it fulfills all the requirements, that are made of such material. It is strong enough to withstand any blows it may receive and at the same time is hard enough to resist the wear to which it may be subjected, better than any known granite or syenite. It does not become smooth and slippery under continual wear as paving blocks consisting of only one mineral or of very fine-grained constituents are known to do.*

In the form of crushed rock for the foundation of macadamized roads this rock has already proved itself very valuable. It should, however, be covered with a layer of denser, finer grained stone, like trap or quartzite, which will withstand the pulverizing action of the wheels longer than the granular "syenite." The blue granite is quite commonly employed as curbing, but it is so hard to work and this class of cut stone commands so small a price that it is not very profitable to use it for this purpose.

b. Crystallographic, Microscopic and Chemical Investigation.

The structure of the blue granite (pulaskite) may be described as being intermediate between hypidiomorphic granular and granitic porphyritic, inclining in some specimens more to the one and in others more toward the other. The form of the feldspar crystals gives a trachytic (see chap. IV. II. C. 1) appearance to the rock.

The following minerals are usually found in every specimen of the rock, but they are present in variable quantities. Especially among the basic silicates is this particularly noticeable since in many cases one of them predominates to the almost complete exclusion of the others.

* See Census Bulletin No. 45 of the Eleventh Census of the United States, March, 1891, page 23.

The minerals are orthoclase (kryptoperthite), hornblende (arfvedsonite), augite (diopside), biotite, eleolite, sodalite (rare), titanite, apatite, etc.

This rock corresponds in some respects to the third variety of augite syenite mentioned by Rosenbusch (Mik. Physiog. Band II., p. 70) and described by Brögger* (Silur. Etagen, p. 256.) Brögger called the rock which he described in the Silur. Etagen augite syenite, but in his later publication he gave the local name laurvikite to it (Syenitpegmatitgänge, p. 28.) The Norwegian rock is characterized by a peculiar form of feldspar, which does not exist in the Arkansas rock, and hence a complete similarity cannot be established between the two rocks†. Ordinarily the Arkansas rock is much richer in hornblende (arfvedsonite) than the laurvikite or the augite syenites in general and must be considered as a trachitic form of an eleolitic hornblende syenite. Such a rock has not as yet been described and the writer suggests the name PULASKITE—that of Pulaski‡ county in which the city of Little Rock and

* W. C. Brögger, now Professor of Mineralogy and Geology in the high school in Stockholm, published in 1882, a work entitled "Die silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker, ihre Gliederung, Fossilien, Schichtenstörungen und Contactmetamorphosen von W. C. Brögger, Kristiania, 1882." In this he describes especially the sedimentary rocks and their fossils, but at the same time gives a short description of the igneous rock of that region.

In 1890 the same author published a work entitled "Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite von W. C. Brögger mit zahlreichen chemisch-analytischen Beiträgen von P. T. Cleve U. A., Leipsig, 1890." This appeared as the sixteenth volume of the Zeitschrift für Krystallographie und Mineralogie published by P. Groth and consists of one volume divided into two parts. The first 235 pages are devoted to a geologic description of the region about Christiania, and contain many petrographic descriptions and analyses of the igneous rocks. In the second part of the work the author confines himself, as the title indicates, to the description of the individual minerals which occur in the pegmatite dikes in that region. The author of these valuable works is now preparing a monograph upon the igneous rocks of the same region, in which he will discuss their petrographic characteristics and relations more fully than he has done in either of the preceding publications. It is for this petrogrophic monograph that many of the analyses published in the Syenitpegmatitgänge were prepared.

As numerous references will be made in this report to these two works, they will be designated in the text simply as (Silur. Etagen, p. —), for the earlier, and (Syenitpegmatitgänge, p.—) for the latter, and thus many long titles and numerous foot notes will be avoided.

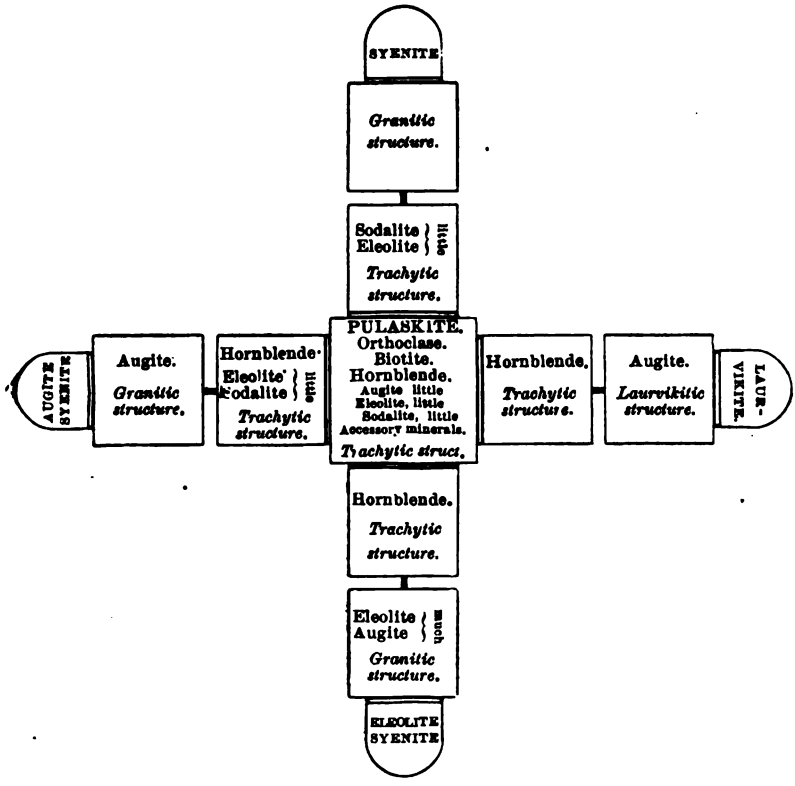
† Professor Rosenbusch has kindly informed the writer that although the typical laurvikite is not identical with the Arkansas rock, certain varieties of the former resemble it very closely.

‡ The county was named after Count Casimir Pulaski, a Polish patriot, who fought on the American side during the war of the Revolution and was killed at the siege of Savannah, Ga., in 1779.

Fourche Mountain are situated—as a designation for this type of rock§.

The relation of pulaskite to the rocks which it most closely resembles is represented by the following diagram:

Graphic representation of the relation of pulaskite to the allied rocks.



The minerals and structures enclosed in the squares nearest to the various rocks mentioned represent the ingredients and properties which those rocks possess and the others lack. Thus pulaskite contains hornblende and has a trachytic structure, while laurvikite contains augite in

§ As this is going to press word has been received from Professor W. S. Bayley of Colby University, Waterville, Maine, that he has found the rock from Red Hill, N. H., described as hornblende syenite by G. W. Hawes (Mineralogy and Lithology of New Hampshire, 1878) to be an eleolite syenite, and consequently a hornblende eleolite syenite. The New Hampshire rock is, however, quite unlike that from Arkansas in appearance and structure.

large quantities and little or no hornblende and has a laurvikitic structure.

Orthoclase is by far the most important mineral in the rock. It appears usually in two distinct generations. The crystals, which belong to the first generation, are large (10–30 mm in length) and often show an idiomorphic form, although this is frequently hidden by the beginning of the crystallization of the minerals of the second generation, before that of the first was entirely completed.

It is seldom that the external form can be observed, but in a slightly weathered specimen of the blue rock, containing very large crystals, individuals were found showing the following faces: $0P$ (001), $\infty P\bar{\infty}$ (010) and ∞P (110). Some of these crystals were twins parallel to the base (100), while the others were Carlsbad twins. In one case, these two laws were observed combined in the same crystal. These large orthoclase phenocrysts are for the most part very impelucid, but in some cases they are partially transparent in the center. A kaolinization has evidently taken place from the outside, and has worked inward leaving the centers of the larger crystals comparatively fresh.

The crystals have two systems of cleavage-planes parallel respectively to the base (001) and the clinopinacoid (010).

Several of these crystals were kindly measured by Professor J. F. Kemp of Cornell University, with the following results:—

P : M (1)	89°	57′
(2)	90	03
(3)	90	00
Mean	90	00

Another piece, on which the faces were not quite so perfect, gave a variation from 90° of 8½ minutes, but it is certain that the first readings are the more correct. It is evident, therefore, that the crystal is monclinic in its habit.

Under the microscope some of the feldspar crystals are seen to contain small cavities, elongated in such a way as to

give the appearance of minute, black needles. These are generally arranged parallel to each other and are found either at right angles to, or parallel to the cleavage-planes. A few larger cavities have been observed, which appear to contain fluids, in which stationary gas bubbles often appear. In many crystals an indistinct microperthitic structure has been observed.

When viewed in convergent polarized light the optic axis angle of the feldspar is seen to be small, not over 30°, but it has not, however, been accurately measured in any of the specimens. In all cases in which it has been observed it has been found to lie in the symmetry-plane (010).

The feldspar contains as inclusions besides the basic silicates, apatite, magnetite and not infrequently irregularly bounded grains of eleolite or nepheline. If several of these are included in the same individual, they are generally all extinguished at the same time when examined between crossed nicols. They appear to be arranged without any regularity so far as the crystallographic form of the including mineral is concerned.

The chemical analysis corresponds with the preceding observations, and shows that the mineral is an isomorphic mixture of a potassium and sodium polysilicate.

The following analysis was made by the Survey, W. A. Noyes, professor of chemistry at the Rose Polytechnic Institute, Terre Haute, Ind., analyst:—

Analysis of Kryptoperthite from Fourche Mt.

SiO_2	66.95
Al_2O_3	17.87
Fe_2O_3	0.90
CaO	0.52
MgO	0.24
K_2O	7.82
Na_2O	5.20
H_2O (loss on ignition)	0.30
Total	99.80

The silica appears to be a little too high and the alumina a

little too low, when compared with other analyses of orthoclase rich in sodium.

When all the facts mentioned above are taken into consideration, it is evident that the feldspar is a sodium orthoclase and is very similar to, if not identical with, Brögger's *kryptoperthite* (Syenitpegmatitgänge, p. 524), although the amount of soda is somewhat less than is usually found in this. For the sake of comparison the following analyses from Brögger's work are quoted :—

Analyses of Feldspars.

CONSTITUENTS.	I.	II.	III.
	Fourche Mt	Fredriksvarn.	Laurvik.
SiO_2	66.95	66.06	65.90
Al_2O_3	17.87	18.77	19.46
Fe_2O_3	0.90	.....	0.44
CaO	0.52	0.37	0.28
MgO	0.24	.....	.....
K_2O	7.82	7.68	6.55
Na_2O	5.26	6.54	6.14
Loss on ignition	0.30	.....	0.12
Total	99.80	99.44	98.90

I. Feldspar from Fourche Mt., Arkansas—Anal. by W. A. Noyes.

II. Kryptoperthite from Fredriksvarn, Norway—Anal. by G. Flink.

III. Kryptoperthite from Laurvik, Norway (in green eleolite)—Anal. by G. G. Gmelin.

The agreement of these various specimens is sufficiently close to establish their identity.

Plagioclase seems to be entirely wanting, as no crystal of it has been observed in any of the fifty or more sections of this rock which were examined.

Quartz does not appear in this rock.

The dark colored minerals which occur in this rock are usually collected together in small groups, and it is only very seldom, that single crystals are found scattered among the orthoclase individuals. These basic silicates are naturally all idiomorphic with regard to the younger light colored silicates, but

among themselves they show peculiar intergrowths. Of the three, biotite is evidently the oldest, as each of the others in turn surround it. Hornblende comes next in order, and the pyroxene is the youngest.

Biotite (black mica) is of a black color, and occasionally shows an apparently hexagonal form, but it is more often found in irregularly bounded plates. It is especially distinguished by its perfect cleavage parallel to the base (001). In some of the darker varieties of the blue granite (pulaskite), it shows a peculiar bronzy lustre, which makes it very conspicuous, especially in a polished surface. In such cases it is quite brittle and filled with innumerable inclusions of other minerals, principally apatite and feldspar, in irregular grains.

In thin sections, the biotite usually appears as irregularly bounded pieces of a reddish brown to a dark brown color, showing very strong pleochroism with the usual absorption. The plane of extinction appears to be very nearly at right angles to the cleavage-planes. The crystals are sometimes scattered irregularly through the section, but are more often clustered together with the other basic silicates into small nests or groups indicating a secondary character for some of them.

Plates parallel to the base (001) (cleavage-plates) show in convergent light that the mineral is almost uniaxial. The axial angle seldom if ever exceeds four degrees, and is usually found to be less. In all cases where the position of the axes could be determined they were found to lie parallel to the symmetry-plane, showing that the mica is a meroxene and not an anomite. The character of the double refraction is negative, and the dispersion of the axes and bisectrix is as usual in such micas.

The only inclusions which have been observed are magnetite and apatite. The latter is very common and often constitutes a good part of the plate.

Pyroxene occurs in comparatively small, thick, greenish black crystals, which are difficult of detection macroscopically. Under the microscope they appear as very light green, or nearly colorless crystals, often idiomorphic and showing the forms

$\infty P\bar{\infty}$ (100), $\infty P\breve{\infty}$ (010) and ∞P (110), but also frequently allotriomorphically bounded and grouped together with other individuals into small aggregations.

Under the microscope the cleavage, in sections at right angles to the vertical axis, appears as sharp lines cutting each other at approximately 87°, and lying parallel to the prism faces (110). There appears also in such sections an indistinct separation, which can hardly be called a cleavage, approximately parallel to the orthopinacoid (100). In sections parallel to the vertical axis the prismatic cleavage appears in the form of parallel cracks, usually highly inclined to the surface of the sections. Here also appears a system of irregular cracks which in this case lie approximately parallel to the base (001).

Twins are not common, but some crystals have been observed which were made up of two individuals twinned parallel to the orthopinacoid (100). In a few cases sections at right angles to the vertical axis of the crystal, show a plate parallel to the orthopinacoid (100), interposed between the two halves of the inclosing crystal.

Observed in parallel polarized light, the basal sections show total extinction, when the cross-hairs bisect the angles made by the cleavage-cracks, and hence lie respectively parallel and perpendicular to the symmetry-plane.

In the light colored crystals pleochroism is not detectable, except near the edge, but in those which have a decided green tinge, the pleochroism varies between two shades of light green. The formula for the absorption is probably $c>a>b$.

The position of the acute bisectrix, in sections parallel to the plane of symmetry, varies somewhat in different specimens. The angle which it makes with the vertical axis reaches a maximum at about 52°, but it has been observed in some sections, also apparently parallel to the symmetry-plane; to be as small as 40 degrees.

In some cases a zonal structure has been observed where the center of the crystal shows a greater angle of extinction than the outside. Thus in one comparatively large crystal (2 mm long) the central kernel was extinguished at an angle of 51°,

while the outside became dark when an angle of 46° had been reached. In this case the central portion was slightly darker in color than the outside. The reverse of this is, however, usually the case in this rock, and it has generally been observed that while the main portion of the crystal is colorless or nearly so, a slightly greenish edge surrounds it, and that in some cases this edge becomes quite deep in color. There is a marked difference in the angles of extinction measured for the greenish borders and the lighter interiors, the former becoming dark at an angle of not more than 8° to 10°, while the latter show the normal extinction angles of 40° to 50°. It is probable that an ægiritic border was formed about the crystals, by the action of the strongly alkaline magma in which they were produced.

It seems probable from the foregoing considerations, that the principal form of pyroxene found in this rock, is *diopside*, which has been altered about the edge to an ægiritic mineral.

Among the inclusions which have been noted are apatite, magnetite, titanite, biotite, and irregularly distributed gas-pores, some of which reach a diameter of several tenths of a millimeter.

Amphibole occurs in thick, short prisms, seldom exceeding 1 mm in any direction. It is of a jet-black color and presents a black, glistening surface under the magnifiying-glass.

In thin sections under the microscope it usually appears in rich, chestnut-brown, greenish brown, or dark green crystals, which are bounded by the faces ∞P (110), $\infty P\bar{\infty}$ (100) and $\infty P\breve{\infty}$ (010). $0P$ (001) and some orthodome (m0$\bar{1}$) have also been observed. The cleavage-cracks parallel to the two prisms are very sharply defined, and show the usual prism angle for amphibole. In addition to these two systems of cleavage-cracks, there appears another, much less distinct and indicated by but a few cracks, lying parallel to the clinopinacoid (010). The pleochroism is very marked and is as follows:—

parallel to b reddish brown;
parallel to a light yellowish brown;
parallel to c dark reddish brown;

and the absorption is expressed by the formula $c > b > a$.

In other cases where the crystals become more decidedly green the pleochroism becomes:—

parallel to b deep bluish green;

parallel to a brownish yellow;

parallel to c yellowish green;

and the absorption is $b > c > a$.

In polarized light, sections at right angles to the vertical axis are totally extinguished when the cross-hairs bisect the angles made by the prismatic cleavage-planes. In sections parallel to the clinopinacoid (010) the angle of extinction is quite large, 20° having in some places been observed. A dark green edge, or border, surrounds many of the brown crystals, but no difference in the angle of extinction between the center of the crystal and this green band has been detected. Some of the brown crystals are completely free from such a border, but it almost always appears about the greenish ones.

It is probable from the general appearance of these crystals, that they belong to that group of amphiboles known as *arfvedsonite*,* but no chemical tests have been attempted in proof of this supposition. Twin crystals have not been observed.

Among the inclusions may be mentioned those which were enumerated as occurring in pyroxene with the addition of that mineral itself. Gas inclusions are not uncommon, but they play no important part in the physiography of the crystal.

Professor Rosenbusch has informed the writer that the rare and interesting mineral *ainigmatite* (Breithaupt) appears in the form of a slender needle, in a section of a specimen of this rock sent to him for inspection.

The peculiar relations which the three basic silicates described above bear to each other deserve a special mention. It has already been stated that these appear, to a certain extent, to replace each other, so that where one strongly predominates the other two are found in smaller

* Prof. H. Rosenbusch has kindly informed the writer that he considers them to be closely allied to the barkevikite of Brögger.

quantities. This is carried, in some cases, to the almost complete elimination of one or other or both of the less important minerals; at the same time a corresponding increase in the amount of the more important one takes place.

Thus biotite is found in distinct individuals (usually rounded) included in both of the other basic silicates. Where it occurs in the pyroxene, it is occasionally found with its basal cleavage parallel to the vertical axis of that mineral, but this is by no means the rule and appears to be due more to accident than to any inherent tendency of the crystals to arrange themselves in that order. The same may be said of amphibole and biotite. In the case of the intergrowth of the pyroxene with the amphibole it is evident that there is a distinct tendency for them to arrange themselves with parallel vertical axes and with their cleavage-planes so situated that the bisectrices of the included angles fall together. Thus pyroxene crystals may be found which are partially or entirely surrounded by amphibole and which, if they are studied in sections perpendicular to the vertical axis, are found to become dark in parallel polarized light at the same instant with the amphibole crystals. In such intergrowths, sections approximately parallel to the clinopinacoid (010) show a marked difference in the angles of extinction between the two individuals for when the one is dark the other is light. There are many cases where this parallel intergrowth has not taken place and crystals of pyroxene and amphibole are found in irregular combinations. In every case the pyroxene is evidently the older.

Eleolite or nepheline holds an intermediate position between the essential and the accessory minerals. In some specimens it becomes quite insignificant while in others it appears to play quite an important part. It might well be termed a characteristic accessory mineral, which, when present, gives a certain character to the rock, but which when absent, does not necessitate a change of name, nor does it indicate an alteration in the genetic conditions under which the rock was formed.

Eleolite never occurs in this rock as idiomorphic crystals, but always in wedge shaped or polyhedral masses which take their exterior form from the minerals by which they are surrounded. These masses are too small to be readily detected by the naked eye and only in very few cases do they reach a diameter of a millimeter. They are generally colorless or slightly tinged with yellow.

Under the microscope eleolite appears as a transparent, colorless substance which occupies the spaces between the feldspars or other minerals which make up the rock and is usually bounded by a triangular or polygonal outline. It has also been frequently observed as rounded sections included in the large feldspar crystals. These irregular sections seldom show a true cleavage though an uneven fracture through them is not uncommonly observed.

It is a very common thing to find this mineral altered to analcite; in some cases so complete has been this change that in many sections no remnant of the original substance can be found. In such cases it must be assumed that eleolite was the mineral from which the analcite was derived, for as will be described later, analcite has been found in associated rocks surrounding an undecomposed mass of eleolite. Hence it appears more than probable that it is, in this case also, an alteration product of that same mineral.

When the eleolite or nepheline is fresh and unaltered it gives a sharp extinction and shows the negative character of its double refraction in cases where a selenite plate can be used. In convergent polarized light a black cross appears but no rings are visible. Microchemic tests show the presence of gelatinous silica and of sodium.

Brögger (Silur. Etagen. p. 268) describes nepheline of a very similar form, but in the Norwegian rocks the alteration to analcite appears to have taken place in a much less marked degree.

Eleolite is nearly free from inclusions but contains a few needles of apatite and here and there beautiful, slender ægirite crystals (see under secondary ægirite).

Sodalite appears in only a few of the sections and is generally nearly filled with dust-like inclusions. It is for the most part completely altered into undeterminable decomposition products, which have a decided action on polarized light. The sodalite crystals are about half a millimeter in diameter and are generally bounded by the other constituents of the rock, but in a few cases they show idiomorphic outlines. Inclusions of magnetite, apatite and the basic silicates have been observed.

Titanite is by far the most important and most common of the truly accessory minerals. It forms light to dark yellow idiomorphic crystals some of which are as much as 1.5 mm in diameter and may easily be detected macroscopically by their resinous lustre and yellow collor.

Under the microscope these are especially noticeable on account of their sharp outlines and the rough appearance of their surfaces. They are practically free from inclusions and are evidently the first crystals that were formed. Their general characteristics are precisely like those of other rock-forming titanite crystals so they need not be described in detail. Twins are very rare in this rock.

Apatite comes next to the titanite in the order of its formation and in some specimens it becomes quite important on account of the quantity present. Its crystals attain, in some cases, a length of two millimeters and form slender idiomorphic prisms, generally truncated at both ends by pyramidal faces. The characteristic separation cracks approximately parallel to the base are well marked, but the commonly observed dusty appearance in the center of the crystal is wanting. The properties of the mineral are identical with those usually described.

Magnetite occurs sparingly in small idiomorphic grains which are opaque and show a rough surface under the microscope. They seldom exceed a tenth of a millimeter in diameter and are found scattered through almost all the other constituents of the rock.

Fluorite has been observed in minute purple crystals

which remain dark between crossed nicols during a complete revolution of the stage. Cleavage-planes parallel to O (111) are visible. The purple coloring matter appears to be unevenly distributed through the crystal but no optic irregularities have been detected.

Secondary ægirite appears in the form of very minute slender prisms showing the pinacoid and prism faces. Under the microscope it appears of a bright green color and shows an extinction angle in sections parallel to the clinopinacoid (010) of not more than two degrees. The pleochroism is strong. These minute needles show a remarkably dark band about all the edges which is due to the total refraction of the light. The extinction angle is so small that it is often almost impossible to measure it and the crystals appear like epidote needles. It is seen, however, from the sections at right angles to the longest diameter that the crystals belong to the pyroxene and not to the epidote group. These crystals are usually radially arranged about a corner of an amphibole crystal or about a magnetite grain. They are also found scattered singly through some of the light colored components of the rock and are especially frequent in the eleolite (nepheline). It is evident from their mode of occurrence that they are of secondary origin.

Analcite, which has already been mentioned under the head of eleolite or nepheline, plays an important part in the microphysiography of many specimens of the rock under consideration.

It usually occurs in the same form that the eleolite had before it but occasionally extends beyond that border into the feldspar crystals which bounded the original eleolite. It appears as if it had taken some of its material from the feldspar and had grown at its expense. In the majority of cases it appears under the microscope to be of a slightly pinkish or brownish color; it is not wholly transparent but presents a slightly dusty appearance. Between crossed nicols it appears perfectly dark, so far as transmitted light is concerned, but has a slightly pinkish or yellowish appearance

which is due to reflected light. Its index of refraction is low and its surface shows no relief. Such crystals can with difficulty be distinguished from sodalite. In some cases the analcite shows a weak double refraction between crossed nicols, and in such cases these anomalies can be brought out very much more distinctly by the use of a selenite plate. The crystals which show these optic anomalies to the best advantage are at the same time the clearest and lightest in color. Cleavage-cracks at right angles to each other have been observed but, owing to lack of external form, these could not be identified as being parallel to any particular faces of the crystals.

Quartz and *zircon* are entirely wanting. In order to be sure that the latter was not overlooked a quantity of the somewhat decomposed rock was washed in a "batea" or Brazilian mining pan.* The residue, after having been freed from magnetite, was examined under the microscope but without disclosing any rare minerals.

It is evident from the fractured appearance of certain of the minerals in some specimens of this rock, that they were subjected to a good deal of crushing before the rock solidified. Thus in a dark colored specimen of rock from the top of the Fourche Mountain ridge, long biotites are found which have been broken through at right angles to their cleavage-planes and the fragments thus formed have been separated from each other and in some cases pressed out of line. The spaces between the sections have been filled with feldspathic material.

From the foregoing description it will be seen that the pulaskite is an eleolitic (nephelinitic) syenite, in which amphibole usually predominates among the basic silicates, and pyroxene and biotite are present in small quantities. Although generally somewhat finer grained than Brögger's *laurvikite*, and while differing from it in the shape of its feld-

* For the use of this instrument, as applied to the detection of rock-making minerals having a high specific gravity, see O. A. Derby's paper read at the Indianapolis Meeting of the Am. Assoc. for the Advancement of Science. (Proc. A. A. A. S., Vol. XXXIX, 1891.)

spars, it certainly bears a very close relation to that unique form of syenite. That this likeness between the two rocks is not only mineralogic and structural, but also chemical, is shown by the following analyses :—

Analyses of pulaskite and laurvikite.

CONSTITUENTS.	I.	II.	III.
	PULASKITE.		LAURVIKITE.
	Fourche Mountain.	Same slightly weathered.	Norway.
SiO_2	60.03	60.68	58.88
Al_2O_3	20.76	18.77	20.30
Fe_2O_3	4.01	3.40	3.63
FeO	0.75	0.45	2.58(*)
CaO	2.62	2.71	3.03
MgO	0.80	0.93	0.79
MnO	trace	trace	.....
K_2O	5.48	5.72	4.50 (†)
Na_2O	5.96	not determined	5.73 (†)
H_2O (ignition)	0.59	0.97	1.01
P_2O_5	0.07	not determined	0.54
Total	101.07	.....	100.99

Cl and SO_3 are wanting.

I. Light colored pulaskite from Fourche Mountain. Analysis by R. N. Brackett and J. P. Smith.

II. Same, slightly weathered. Partial analysis by R. N. Brackett and J. P. Smith.

III. Laurvikite, light gray, from Byskoven, Laurvik, Norway. Mean of analyses by Stahl and Mannsfeld.‡

* FeO in analysis III includes some MnO.

† Analysis III is a mean of analyses by Stahl, Mannsfeld, and a potassium determined by Cahn. The separate analyses of the alkalies were as follows :—

	K_2O.	Na_2O.
Stahl	4.80	6.46
Mannsfeld	4.60	5.73 (*number used*).
Cahn	4.05	.....
Mean	4.50 (*number used*)	6.09

‡A Merian, Studien an gesteinsbildenen Pyroxenen, N. Jahrb. f. Mineral., Beilageband III., 1884, p. 266.

The occurrence of the pulaskite in a wide dike-like mass when taken in connection with its trachytic, semi-porphyritic structure places it among the intrusive dikes and not with the truly abyssal rocks. In this respect this rock differs not only from the laurvikite but from the augite and eleolite syenites as well.

Segregation veins.—These occur in the pulaskite and have already been mentioned on page 20. They consist principally of large tabular feldspar crystals which often attain a length of more than 25 mm. These are thin, tabular, parallel to the clinopinacoid (010), and are frequently twinned according to the Carlsbad law. The faces which have been observed are as follows: $\infty P\bar{\infty}$ (010); $\infty P\frac{3}{2}$ (130); ∞P (110); $0P$ (001); $+P\bar{\infty}$ (10$\bar{1}$) and $+P$ (11$\bar{1}$). The crystals are white and opaque and are often much etched on the surface.

Ægirite appears in black prisms often 10 to 12 mm in length. The feldspars are generally so arranged as to leave large interstitial spaces, which are occasionally filled with decomposed masses of limonite and are not uncommonly stained black by manganese.

In one specimen given the writer by Dr. W. P. Jenny of the U. S. Geological Survey, the crystals of feldspar were coated with an incrustation of hyalite. This mineral appears in the form of a thin coating of amorphous substance which in many places forms minute globules seldom exceeding 0.5 mm in diameter. Under the microscope these globules appear isotropic and seldom, if ever, show a tendency toward optic activity. The hyalite gives an opalescent appearance to the surface of the feldspar and when colored with limonite or manganese oxides, as it often is, it imparts a dark vitreous lustre to the surface upon which it occurs.

That these veins are segregations and not pegmatitic intrusions, is shown by the fact that they are often very limited in extent and are entirely surrounded by the blue granite (pulaskite).

B. Gray Granite (Eleolite Syenite).

That rock which forms the large flat masses, described as

occurring at the base and for a short distance up the sides of the hills is known by the name "gray granite." It has as yet been quarried to but a small extent, and has been used principally in trimmings for buildings. Owing to its lighter color and inferior strength, it has not become as popular a building stone as the blue granite (pulaskite). The Braddock quarry (see plate 10) has lately been opened near the turnpike on the northwest side of Allis Mountain, and some fresher, better stone, than that found elsewhere has been taken out. The opening is as yet only six or seven feet (1.8 to 2.1 m) deep, and, if on going deeper the stone is found to continue to improve, it will certainly form a very beautiful and durable building stone. It often shows a decidedly gneissic structure and in many cases may be quarried in large flat slabs several square yards (meters) in area in much the same way that a free splitting gneiss or mica-schist is worked. This structure facilitates the working of the rock in a great degree and makes the stone a comparatively cheap building and paving material.

a. Physical Properties.

Structure.—The gray rock is easily distinguished from the blue rock, not only by its color, but by its very different texture. While the blue rock is semi-porphyritic in its structure, this rock is completely granular and has a trachytic structure.

This structure may be seen by an inspection of plate 1 (frontispiece), where an exact reproduction of a polished surface of this rock* is shown.

In most cases the rock consists of large individual crystals, but it also frequently occurs as a fine-grained rock, still preserving, however, the same characteristic granular structure. The feldspar and mica are both conspicuous in this rock and the eleolite also forms a prominent feature. The feldspar is dull and cleaves easily in two directions, so that the appearance of a broken piece of the rock is very rough.

As has been stated, this rock usually forms hugh flat surfaces (see plate 7, p. 29), which seldom show cracks in any direction so that it would be possible to obtain blocks of almost

* The specimen shown is the fresh rock from Braddock's quarry.

EXFOLIATION OF GRAY GRANITE (ELEOLITE SYENITE). BRADDOCK'S QUARRY.

any size from some of them. On weathering it simply crumbles away on the surface but does not break up into blocks as does the blue rock.

Color.—The color of this rock is a light gray, possessing in some specimens a reddish and in others a yellowish hue. This light color is very characteristic, and wherever it appears it is an indication that this eleolite (nepheline) syenite is present. Where the rock becomes finer grained, the color becomes darker and gradually shades into a brown; a transition which is due to the numerous small flakes of mica which often cover up much of the feldspar. When the fresher material from the bottom of the Braddock quarry was examined it was found to show a slightly bluish color, especially in the center of the feldspar crystals. These crystals show that the usual, extremely white color of the feldspars is due to weathering.

Strength.—A cube of this rock was tested in the same way as the blue rock and gave the following result:—

Pressure* per square inch under which cube crumbled..... 14,000 lbs

Corresponding pressure in two inch cube calculated by cubic parabola formula..... 16,000 "

It appears from this that, although the strength is much inferior to that of the blue rock, it is still fully as strong as many true granites and is quite strong enough for all building purposes.† The rock is much softer than the blue rock and it is worked much more easily.

Absorption.—This was determined in the same way that it was for the various kinds of blue granite (pulaskite); it gave the following result after twenty-four hours immersion:—

Ratio of absorption=1 : 145.

This specimen which weighed 11.5 gr was allowed to dry in the air for twenty-four hours and was found to have given up fifteen-sixteenths of its absorbed water at the end of that time.

* This test, like those on the blue rock, was made upon a cube less than two inches on an edge. The figures obtained from the tests before reduction are as follows:—

Area over which pressure was distributed..... 2 sq. in.

Actual pressure under which cube tested crumbled... 28,000 lbs.

† At the time that these tests were made the fresher rock mentioned above had not been quarried.

Specific gravity.—In combination with the absorption test, a determination of the specific gravity of this rock was made and gave the following result:—

Specific gravity=2.557

Weight per cubic foot.—The weight per cubic foot was found from the above to be 159.8 pounds.

Effect of heat.—When heated in the same way as the blue granite (pulaskite) it showed slightly more deterioration than the latter at the same temperatures.

b. Crystallographic, Microscopic and Chemical Investigation.

Structure.—Under the microscope the trachytic character of the eleolite syenite (gray granite) appears very distinctly and the structure is completely hypidiomorphic granular. This rock often shows a miarolitic structure in which the small cavities are bounded by feldspar and mica and contain zeolites.

Feldspar as in the preceeding rock is by far the most important constituent. It appears in crystals which are tabular parallel to the branchypinacoid (010) and often reach a large size. Individuals not less than 75 mm occasionally occur but in general they do not exceed 15 to 25 mm in their greatest diameter.

These crystals are usually opaque, with a dull white, or slightly pinkish or yellowish color. There is a slight reflection of light from the basal cleavage-plane, but in general all the faces present a dull appearance. Twins according to the Carlsbad law, are very common—in fact single crystals are much rarer than twins. Two other cleavage-planes, besides that parallel to the base (001), have been observed. One of them is parallel to the brachypinacoid (010), while the other appears to be parallel to the macrodome $+8P\bar{\infty}$ (80$\bar{1}$). The crystals break easily into small parallepipedons, whose faces correspond to the cleavage-planes just mentioned. The angles of these cleavage-pieces were kindly measured by Prof. J. F. Kemp of Cornell University.

Kemp found the reflections poor, but obtained as a mean of several readings the following angles:—

010 : 001 (M : P)..... 89° 32′
001 : 80$\bar{1}$..... 71 26

This indicates the triclinic form of the mineral and at the same time shows a cleavage similar to that found in orthoclase and sanidine and described for those minerals by Cross, Levy, Graeff, von Jeremejew, Brögger* and others.

The angle of 70° 26′ approaches somewhat nearer to the angle of the macrodome $+9P\bar{\infty}$ ($90\bar{1}$)* than it does to that of $+8P\bar{\infty}$ ($80\bar{1}$), but this may be due to the poor reflections on the macrodome.

Under the microscope this mineral usually appears quite opaque and even in very thin sections it is only semi-translucent. It shows very distinct cleavage-cracks in directions parallel to the base (001) and brachypinacoid (010), and very much less perfect ones in the direction parallel to the above mentioned macrodome ($80\bar{1}$).

In polarized light the crystals show an extinction which, although by no means sharp, is evidently not parallel to the M : P edge in plates parallel to $0P$ (001). An angle of $+9°$ was measured on a cleavage-plate which was thin enough on the edge to show a comparatively sharp extinction.

In very few cases do the crystals appear to be single individuals. In the first place they are almost always twinned according to the Carlsbad law, and in the second place they are completely filled with twinning lamellæ, giving them a very perfect microperthitic structure. These lamellæ do not run completely through the crystal, as in the case of plagioclase, but appear as wedged-shaped bands which narrow to a point before passing more than half way through the crystal.

It is evident from the appearance of the crystals that decomposition has taken place in a very marked degree. In many cases the rock as a whole has become very much kaolinized and finally breaks down to a true kaolin as will appear later. It is evident that the decomposition of the rock is due in a great measure to the weathering of the feldspar and eleolite.

An analysis of a portion of one of these feldspar crystals was

* For the references to the works of these authors see Brögger's Syenitpegmatitgänge, p. 536.

made by the Survey, W. A. Noyes, analyst, with the following results:—

Analysis of microcline-microperthite.

SiO_2	66.39
Al_2O_3	18.13
Fe_2O_3	1.44
CaO	0.16
MgO	0.06
K_2O	8.51
Na_2O	5.36
Ignition	0.42
Total	100.47

From its chemical composition, crystallographic form and microscopic structure this feldspar is evidently closely allied to the *microcline-microperthite* of Brögger (Syenitpegmatitgänge, p. 556). Its chemical composition shows a remarkable similarity with the kryptoperthite described on page 59. The almost complete absence of lime shows that no admixture of a soda-lime feldspar is possible and indicates that the soda must all be present in the form of albite.

Eleolite becomes in the gray granite one of the essential minerals and in many cases forms as much as a fourth of the whole mass of the rock. The crystals appear to be always bounded by the feldspars and therefore never show idiomorphic forms. They are of a brownish yellow, or lemon yellow color and present on broken surfaces the characteristic greasy lustre, which gave the mineral its name. In some cases the eleolite including its decomposition product analcite, occupies spaces not less than 10 mm in length. It often takes the form of a thin, flat plate and lies along the side of a feldspar crystal, occupying the space between it and some other crystal or group of crystals.

Under the microscope the eleolite shows its usual characteristics. Its allotriomorphic form is everywhere observed and the peculiar triangular and polygonal sections are very characteristic. Irregular cleavage-planes are observable. Its double refraction is, in general, somewhat stronger than it was in the case of the pre-

ceding rock. In convergent polarized light a wide, black cross appears in sections which are cut nearly at right angles with the principal axis. By means of a quarter-undulation mica plate the character of the double refraction was determined to be negative. The eleolite has in many cases been completely altered to analcite, but as this mineral, like the former, is clear and transparent the spaces occupied by them together are easily distinguished from the white, nearly opaque feldspars.

The eleolite is comparatively free from inclusions of all kinds but ægirite and some of the other basic silicates appear in it in small quantities. Gas and liquid inclusions are seldom observed. Unaltered eleolite is comparatively rare and appears only as a central kernel surrounded by analcite.

Quartz and *plagioclase* are entirely wanting.

Under the head of basic silicates biotite and augite are the only ones present in any quantity, while amphibole is almost or completely wanting.

Biotite is much the more common of the two silicates mentioned and often occurs in large crystals. These frequently attain a diameter of 20 to 25 mm and are often as much as 3 mm in thickness. They form six-sided plates or prisms and are of a deep brown or black color. Their cleavage is very perfect but in some cases where decomposition has begun they have lost their elasticity and at the same time have become brittle. Under the microscope they show the usual characteristics of biotite. The optic axis angle is about 3° and the optic axes lie in the symmetry plane, showing that the mica is a true meroxene and not an anomite. Inclusions are rare.

Pyroxenic minerals.—Under this head are included two forms of pyroxene, namely, diopside, frequently with a diallage-like structure, and ægirite. The *diopside* is in size, color, pleochroism and in fact in most essential respects identical with that found in the pulaskite (p. 63) but differs slightly from it in that it has a darker and wider, green ægiritic border. The extinction angle was found in one crystal to be 6° for the outside and 44° for the inside. *Ægirite* also occurs independently in large crystals some of which are as much as 8

mm long and 2 mm in the direction of their ortho-axes. These crystals are of a brilliant lustre and a greenish black color and are bounded by the prisms (110) and the orthopinacoid (100). The ends appear rough and show no truncations. The angle of extinction was determined in a section cut parallel to the clinopinacoid (010) and was found to be 4°30′. The pleochroism is not very marked but varies between different shades of bluish green. The absorption is greatest parallel to the vertical axis. $a > b > c$ (a lies nearly parallel to c).* The distribution of color is not uniform throughout the crystal being more intense in some parts than in others.

Of the minerals just described the biotite is evidently the oldest, for it often appears completely surrounded by the ægirite and in some cases by the diopside.

Amphibole is entirely wanting in such sections of this rock as have been examined.

Titanite occurs in large idiomorphic crystals which in some cases attain a diameter of 2 mm. It exhibits the usual macroscopic and microscopic characteristics.

Magnetite occurs in small crystals which often have the form of slender rods whose length is several times their breadth.

Apatite occurs in small prisms slightly stouter than usual, but it is much less common than in the pulaskite. It is included in the feldspar and eleolite (or its decomposition products) and is easily recognized by its parallel extinction, negative double refraction and relatively high index of refraction.

Fluorite appears in a few sections; it is of a purple color and perfectly isotropic.

Analcite has already been mentioned under the head of eleolite as being one of the more important decomposition products found in this rock. It occurs in large, clear, colorless or slightly yellowish masses which seldom show any crystal form. In a few cases however the form of the cube (100) and the icositetrahedron (211)have been clearly distinguished and their angles measured. The cleavage parallel to the faces of the cube is generally visible.

* H. Rosenbusch, Mikrosk. Physiographie. Band I., p. 454, note.

In thin sections the crystals appear as colorless, transparent individuals included between the opaque feldspars. In most cases these clear portions are bounded by straight lines, but instances are not few in number in which the analcite has been formed at the expense of the feldspar material, and in such cases the boundary between the two minerals is very irregular. The analcite appears to have eaten into the feldspar wherever it could get a chance, and many feldspars may be found whose centers have become almost entirely changed into analcite, while others have been eaten away on one side, the rest remaining intact. Small pieces of analcite have been detached and tested in various ways. They gelatinize easily with hydrochloric acid, and show cubes of salt under the microscope when the solution is evaporated to dryness. When heated in a closed tube a quantity of water is given off. Tests for chlorine and sulphuric acid gave negative results, so that it is evident that sodalite and haüyne or nosean are not present.

In parallel polarized light the analcite is either perfectly isotropic or shows only very weak double refraction. By means of a selenite plate this double refraction is shown to be irregularly distributed throughout the section, and the appearance is exactly that which is usually found in analcite crystals cut at random.

A section cut parallel to a face of the cube (100) showed the presence of four sectors; one pair of diametrically opposite sectors when examined under the microscope with a selenite plate appeared yellow, while the other pair appeared blue.

Small needles of ægirite of a second generation often occur scattered through the analcites. The primary apatites of the rock are also usually quite plentiful as inclusions, but with these two exceptions the mineral in question is quite free from interpositions of foreign material.

In a few cases a second decomposition has taken place, and radiate needles are found inside of the analcite crystals. These appear, from their parallel extinction, negative character, strength of their double refraction and their association with analcite to be cancrinite. They are extremely minute, being at

the most not over one tenth of a millimeter in length and not exceeding two hundredths of a millimeter in thickness.

Thomsonite has been observed in direct association with the analcite as a decomposition product of the nepheline and feldspar. It occurs in well bounded crystals when it extends in cavities in the rock, but it is usually found without crystallographic terminations. It differs from analcite in showing a cleavage in only two directions at right angles to each other, instead of in three, and in being decidedly anisotropic. The plane of the optic axes was found in one of the well terminated crystals to lie parallel to the base (001). The cleavage parallel to the pinacoids (100 and 010) was good and the surface showed a mother-of-pearl lustre. A microchemic test showed the presence of lime and soda. The mineral was decomposed by hydrochloric acid, with the separation of gelatinous silica.

Secondary ægirite occurs in small prisms as mentioned under analcite. They are often grouped into radiate masses and lose their individual forms, but when they occur as single, isolated crystals they are very perfect and show the forms ∞P (110) and $\infty P\bar{\infty}$ (100) very sharply defined. The cleavage parallel to ∞P (110) is very distinct. The extinction appears to be nearly parallel to the vertical axis and the small angle of extinction is difficult of measurement in such minute crystals.*

Calcite and *kaolin* are found in cases where the decomposition has gone very far. It is to the kaolinization of the feldspathic minerals in this rock that the large beds of kaolin found south of Fourche Mountain are due.†

From a chemical standpoint the eleolite syenite (gray granite) is considerably more acid than would be expected, when the facts that eleolite is present in large quantities and that the rock contains no quartz, are taken into consideration. It contains eight per cent more silica than Brögger's *laurdalite* (Syenitpegmatitgänge, p. 33), which it resembles in so many other respects. The total amount of alkalies present is about the same as in the Norwegian rock, but they are not similarly divided, the

* Compare F. F. Graeff, N. Jahrb. f. Mineral. Jahrgang 1887., Band. II., p. 254.

† See Vol. I. of the Annual Report of Geological Survey of Arkansas for 1889.

sodium not being so much in excess in this rock, as in that from Norway.

Although the analyses of these two rocks do not show any striking similarity they are set side by side for comparison, and with these are placed several analyses of eleolite syenite from other localities.

Analyses of eleolite syenite.

CONSTITUENTS.	I.	II.	III.	IV.	V.	VI.	VII.
	Arkansas	Norway	Portugal	Portugal	C. Verd. Islands.	Brazil	Arkansas
SiO_2	59.70	51.90	54.61	54.20	55.76	56.30	60.08
TiO_2	.....	.....	0.09	1.04	.....	.....	.....
Al_2O_3	18.85	22.54	22.07	21.74	21.61	24.14	20.76
Fe_2O_3	4.85	4.03	2.33	0.46	1.65	1.99	4.01
FeO	.....	3.15	2.50	2.36	4.09	.....	0.75
CaO	1.34	3.11	2.51	1.95	2.26	0.69	2.62
MgO	0.68	1.97	0.88	0.52	0.74	0.13	0.80
MnO	.....	.....	.....	0.11	.....	.....	trace
K_2O	5.97	4.72	5.46	6.97	5.84	6.79	5.48
Na_2O	6.29	8.18	7.58	8.69	6.94	9.28	5.96
P_2O_5	.....	.....	0.15	.....	.....	.....	0.07
H_2O (Ignition)	1.88	0.22	1.13	2.32	3.49	1.58	0.59
Total	99.56	99.82	99.31	100.36	101.88	100.90	101.07

I. Eleolite syenite (gray granite) from Fourche Mountain, Arkansas, by W. A. Noyes.

II. Laurdalite (eleolite syenite) from Lund, Norway, by G. Forsberg. (Brögger, Syenitpegmatitgänge, p. 33.)

III. Eleolite syenite from Caldas de Monchique, Portugal, by E. Kaleszinsky, (A Merian, "Studien an gesteinsbildenden Pyroxenen" N. Jahrb. f. Mineral., Beilageband III., 1884, p. 271.)

IV. Foyaite (eleolite syenite) from Serra de Monchique (Cerro da Posada), Portugal, by P. Jannasch. (N. Jahrb. f. Mineral., Jahrgang 1884., Band II., p. 11, also Gesammelte chemische Forschungen von P. Jannasch, Band I., Göttingen, 1888, p. 181.)

V. Eleolite syenite from S. Vicente, Cape Verd Islands by C. Dölter. ("Die Vulkane der Capverden und ihre Producte." Graz, 1882. Cited from Merian, loc. cit.)

VI. Nephelinsyenit (eleolite syenite) from railway tunnel between Prata and Cascada, São Paulo, Brazil, by J. Machado. "Beitrag zur Petrographie der sudwest. Grenze sw. Minas-Geraës und S. Paulo." (Min. petrog. Mitth. Band IX., 1888, p. 334.)

VII. Pulaskite (blue granite) from Fourche Mountain, Arkansas, by R. N. Brackett.

From the foregoing description it is evident that the gray granite is a true eleolite syenite. It differs somewhat from the majority of eleolite syenites which have been described from other localities and appears, as far as its mineral and chemical composition is concerned, to hold an intermediate position between Brŏggers laurdalite and laurvikite, but in its structure it is much more like the former.

Special attention is called to the great similarity in chemical composition between the pulaskite (VII.) and the eleolite syenite (I) from Fourche Mountain, but the discussion of the significance of this remarkable resemblance must be deferred until the genetic relations of the rocks of this region are considered. (See chap. IV. v.)

In connection with these analyses of comparatively fresh material the following analyses are of interest as showing the composition of the kaolin mentioned above which was derived principally from this material. The following partial analyses were made by the chemist of the Survey and show very clearly the gradual decrease in silica and increase in water as the decomposition proceeded.

Analyses of decomposition products of Fourche Mountain syenite.

CONSTITUENTS.	I. Decomposed Syenite.	II. Decomposed Syenite.	III. Kaolin.
SiO_2	58.50	50 65	46.27
TiO_2	.....	0.06	.....
Al_2O_3	25.71	26.71	38.57
Fe_2O_3	3.74	4.87	1.36
CaO	0.44	0.62	0.34
MgO	Trace	0.21	0.25
K_2O	1.96	1.91	0.23
Na_2O	1.37	0.62	0.37
H_2O	5.85	8.68	13.61
Total	97.57	94.33	101.00
H_2O at 110° Centigrade	.....	.....	1.57

I. Decomposed syenite from railway cut 2 miles north of Sweet Home.

II. Decomposed syenite from railway cut 2 miles north of Sweet Home (another specimen).

III. Kaolin from 1 S., 12 W., section 9.

Another product formed by the breaking down of this or more probably of the pulaskite (blue granite) has been described as occuring at two points about the mountain (pp. 23 and 26). In both of these exposures the material has been consolidated into a comparatively hard rock and the particles are cemented together by secondary silica of both cryptocrystalline and chalcedonic varieties.

Under the microscope the fragments of orthoclase in this rock show very decidedly their detrital origin. In some cases they are comparatively fresh, while in most specimens they are very much decomposed. They often show only a cast of their original form consisting of iron oxide, secondary muscovite and kaolin.

In some cases irregular fragments of siliceous shale have been observed lying among the fragments of feldspar but they are as a rule quite scarce.

A partial analysis of the less siliceous variety of this rock, which occurs as described on page 23, was made by the chemist of the Survey, with the following results:—

Analysis of detrital material.

SiO_2	65.84
Al_2O_3	22.82
Fe_2O_3	2.70
Ignition	2.93
By diff. (CaO alkalies, etc.)	5.71
Total	100.00

It is probable that the variety described on page 26 would give a much larger percentage of silica.

C. Syenitic Dike Rocks.

1. Brown Granite. (Eleolite Syenite Dike Rock).

Under the head of brown granite are included two of the

syenitic dikes which are found southeast of Fourche Mountain (p. 25). They form narrow bands not often exceeding 6 m (20 feet) in width and are so weathered that nothing but a line of boulders remains to show where the dike once was. Although occurring only in boulders this rock has been used to some extent as a building stone. The basement wall of the Pulaski county court house and a large portion of the Roman Catholic cathedral in Little Rock are built of it. It presents a very pleasing contrast to the blue granite (pulaskite) which is used in the superstructure of the court house. In the case of the cathedral, where it has been used indiscriminately in the wall with the blue rock of both coarse and fine grain, the effect is not nearly so good.

Another rock which belongs to this group, is that which forms the bosses and boulders between Fourche Mountain proper and the ridge next south of it (p. 20). It is of a lighter more decidedly gray color than most of the brown granite but still has the structure and general characteristics of the dike rock.

a. Physical Properties.

Structure and color.—This rock is of a grayish brown color and presents a somewhat porphyritic appearance.* The most conspicuous crystals are comparatively large [15–30 mm] feldspars, which are tabular parallel to the symmetry-plane, and which give a trachytic appearance to the rock. These crystals often have a bluish center consisting of a fresh glassy material, while the outside is reddish brown and dull. This imparts a mottled appearance to the rock when seen near by, but which is lost when the rock is viewed at some distance. This alteration in color from the center of the crystals to the outside is probably due to the action of weathering, for in some cases the rock is so fresh that these variations do not appear.

Strength.—Since this rock has been used as a building stone,

* The lithograph, plate 1 (frontispiece) shows the appearance of a polished surface of this rock.

a block of it was tested in the same way that the blue and gray varieties were, and with the following results :—

Pressure* per square inch under which cube crumbled ..... 21,000 lbs.

Corresponding pressure per square inch in 2 inch cubes, calculated by cubic parabola formula..... 25,000 "

The specimen upon which this test was made was not perfectly fresh and was badly jarred in its preparation, so that in all probability a fresh specimen of this rock would stand even more pressure to the square inch than the one used.

The other physical properties determined are as follows :—

Absorptiveness..... 1 : 161
Specific gravity..... 2.521
Weight per cubic foot.....157.6 lbs.
Weight per cubic meter.....2524.47 kilos

b. Crystallographic, Microscopic and Chemical Investigation.

Structure.—The structure of the eleolite syenite dike rock is hypidiomorphic granular. The orthoclase is the most important constituent and generally forms large tabular crystals which are allotriomorphically bounded when they come in contact with the basic silicates or with each other, but are idiomorphic where they come in contact with eleolite or its decomposition product, analcite. These tabular feldspars give a trachytic† appearance to the rock.

From its occurrence in dikes it is evident that this rock belongs to the group of intrusive rocks. Its structure is such

* As on p. 73 the actual results of the tests before reduction are represented by the following figures :—

Area over which pressure was distributed..... 1,426 sq. inches
Pressure under which the cube crumbled..... 30,000 lbs.

† Brögger (Syenitpegmatitgänge, p. 39) suggests that the name *foyaite* be applied to such rocks having a trachytic structure, and at the same time he states that such rock has nothing in common with the rock now bearing that name.

The writer is unwilling to adopt Brögger's name as it seems to lead to confusion by having one name for two different rocks of the same group. If a name for such rocks having a trachytic structure is required, some new name should be chosen which has no established meaning. In this report and until some such name is suggested the writer has chosen to use the expression *eleolite syenite dike rock*, as expressing the coarse grained hypidiomorphic granular structure of the rock and its occurrence as an intrusive dike.

that it falls into the class of granitic eleolite dike rocks, and forms an additional example of this rare rock.*

Orthoclase as has already been stated occurs in crystals which are tabular parallel to the clinopinacoid (010) and consist of a bluish, transparent center, surrounded by a pinkish or brownish, opaque, outer coating. The larger crystals are often 15 to 30 mm in their greatest diameter but not more than 3 or 4 mm in thickness. They are bounded by the faces $\infty P\breve{\infty}$ (010), ∞P (110), $0P$ (001), and $+2P\bar{\infty}$ (201). Under the microscope the difference between the transparent center and the opaque outside is very marked. The two portions are not separated from each other by a sharp line but penetrate one into the other and shade gradually into each other. In the case of many of the smaller crystals the whole section has become opaque. The cleavage-cracks parallel to the base (001) and clinopinacoid (010) are very distinct in such opaque crystals, and appear as white lines in a gray ground. The cracks parallel to the base are sharp and straight, while those parallel to the vertical axis more often appear as if they were simply lighter bands, still very narrow, but not showing the same sharp edge that those parallel to the base (001) exhibit. Twins according to the Carlsbad law are not uncommon, but twinning lamellæ showing the interposition of trielinic feldspar have not been observed. Inclusions of apatite, magnetite and basic silicates have been observed and in some cases the latter are seen to have been altered to serpentine.

Biotite appears in considerable quantity, and is in every respect similar to that found in the eleolite syenite (p. 77).

Pyroxene appears to consist principally of diopside, which is here almost identical with that described in the pulaskite (p. 61). The green edge or border is, however, in this case wider and more prominent than in the mineral already described. The border shows a small extinction angle, which indicates its ægiritic character. The inclusions are similar to those of the already described mineral. In several cases this mineral has been found broken in two and the crack filled with intruded eleolitic

* See Mikros. Physiog., Rosenbusch, Band II., p. 277.

material. The break shows that there was a not inconsiderable dynamic force brought to bear upon the rock after the basic silicates were formed and before the final solidification took place.

Amphibole is entirely wanting in the sections which have been examined.

The biotite and pyroxene are grouped together in much the same way as they are in the pulaskite. The biotite is always the older and is often included by the pyroxene.

Eleolite holds a similar position to the other minerals that it did in the pulaskite, but it is here much more important. It is in almost all cases altered to analcite.

Apatite, *titanite* and *magnetite* are all present in large idiomorphic crystals, but show no peculiarities worthy of description.

Alteration products.—The eleolite has in a great part been altered to *analcite*, as is the case in the pulaskite, but as its optic anomalies and other microscopic characteristics are virtually identical with those there enumerated the description need not be repeated.

Serpentine indicates the beginning of decomposition in the basic silicates of some of the less fresh specimens of the rock. In many cases the dark silicates are surrounded by a narrow band of serpentine. In the orthoclase crystals small spots of serpentine are occasionally found, which indicate that some small included basic silicates have been entirely converted into this substance.

Cancrinite has been observed here and there in very minute grains*.

Calcite has in one or two cases been observed in association with eleolite or analcite and it evidently marks the last stage of the alteration of that mineral.

Chemical constitution.—This brown dike rock is in some respects related to both of the already described varieties of syenite. In its general appearance it resembles the pulaskite more than it does the eleolite syenite, but in the microscopic investi-

* For a description of this mineral see chapter VII. II. B. 1.

gations it is seen to have more the structure and characteristics of the latter. The analyses of the pulaskite and eleolite syenite are so similar that no distinctive points can be found.

An analysis of this dike rock made by the Survey, W. A. Noyes, analyst, gives the following figures (analysis I) which are placed side by side with those of the blue and gray rocks for the convenience of comparison. Analysis II is a determination of the silica in the grayish variety of dike rock (pp. 20 and 84) by R. N. Brackett. It shows that the silica is in this case about one per cent higher than in the reddish brown variety of the dike rock. After a careful search no quartz was found in this grayish variety of the dike rock, but the eleolite was seen to be larger and more important than is common in the brown variety. This would suggest a lower percentage of silica instead of a higher one, as found.

Table showing composition of syenites of Fourche Mountain.

CONSTITUENTS.	I. Dike rock. (brown.)	II. Dike rock. (gray.)	III. Eleolite syenite.	IV. Pulaskite.
SiO_2	59.23	61.10	59.70	60.08
Al_2O_3	19.98	.....	18.85	20.76
Fe_2O_3	4.72	.....	4.85	4.01
FeO	.....	.....	.....	0.75
CaO	2.41	.....	1.84	2.62
MgO	1.10	.....	0.68	0.80
K_2O	5.76	.....	5.97	5.48
Na_2O	5.47	.....	6.29	5.96
P_2O_5	.....	.....	.....	0.07
H_2O (Ignition)	1.38	.....	1.88	0.59
Total	100.05	.....	99.56	101.07

I. Eleolite syenite dike rock (brown granite), S. E. of Fourche Mountain region N. E. of section 35. Reddish brown variety. Anal. by W. A. Noyes.

II. Same. South of Fourche Mountain proper. On line between sections 18 and 19, and one quarter mile east of township line. Silica by R. N. Brackett.

III. Eleolite syenite (gray granite). S. W. ¼ of section 26. Anal. by W. A. Noyes.

IV. Pulaskite (blue granite.) Inside of Fourche Cove, S. W. ¼ of section 13. Anal. by Brackett and Smith.

From its geologic position and physiographic relations it appears as if this brown rock were simply forced into narrow cracks in the Paleozoic shales, while the eleolite syenite formed a much larger mass of similar material, which cooled slower and under pressure. Its occurrence as dikes would place it among the older intruded rocks, while its structural features suggest that it might belong to the eleolite syenite proper.

In its microscopic appearance this rock is almost identical with Brögger's *nordmarkite* (Syenitpegmatitgänge, p. 54.) The latter is a quartz syenite, while the brown rock from Arkansas shows no quartz whatever. The chemical composition of the two rocks is, however, quite similar as is shown by a comparison of the analyses.

Comparison of analyses of syenite from Arkansas and Norway.

CONSTITUENTS.	I. Dike rock (brown) Ark.	II. Dike rock (gray) Ark.	III. Nordmarkite. Norway.
SiO_2	59.23	61.10	60.45
Al_2O_3	19.98	.....	20.14
Fe_2O_3	4.72	.....	3.80
CaO	2.41	.....	1.68
MgO	1.10	.....	1.27
K_2O	5.76	.....	5.12
Na_2O	5.47	.....	7.23
H_2O (ignition)	1.38	.....	0.71
Total	100.05	.....	100.40

I. Eleolite syenite dike rock (brown) Fourche Mountain, Arkansas. Anal. by W. A. Noyes.

II. Eleolite syenite dike rock (gray) Fourche Mountain, Arkansas. Silica by R. N. Brackett.

III. Nordmarkite (quartz syenite). Principal rock, between Loken and Aueröd, Norway. Anal. by G. Forsberg (Syenitpegmatitgänge, p. 57).

The similarity in the macroscopic appearance of these two rocks was first noticed by Professor Rosenbusch, of Heidelberg, who called the writer's attention to it, and through the kindness of Dr. George H. Williams of Johns Hopkins University, Baltimore, the writer was enabled to compare specimens of the two rocks.

When microscopically examined these two rocks are not as similar as their macroscopic appearance and chemical compositions would suggest. Nordmarkite contains a large amount of microperthitic orthoclase, considerable quartz and comparatively few basic silicates. Pyroxenes of the diopside series form the greater part of the basic silicates, but ægirite is also very common and hornblende of the arfvedsonite series is seldom if ever absent. Biotite is often present in large quantities.

It appears, therefore, from the above description that the Arkansas "brown granite" differs very materially from the Norwegian nordmarkite not only in the absence of quartz and the presence of eleolite but also in the relative quantities and the characters of the basic silicates present.

The similarity of this rock in its structure, mineralogic components and mode of occurrence, to Brögger's *foyaite* (Syenitpegmatitgänge p. 39) has already been noted (p. 85) and commented upon.

2. *Miarolitic Dikes.*

a. Miarolitic Eleolite Syenite Dikes.

Under the head of miarolitic eleolite syenite are classed those coarsely crystalline dikes, which have been described as occuring along the northeast ridge of Fourche Mountain and at the southeast corner of the mountain, as well as those which penetrate the fourchite and shales at the south end of Allis Mountain near its summit. They usually occur as very much weathered boulders and in narrow, vein-like masses cutting through other rocks.

Macroscopic structure.—Where the igneous rock has come through other igneous rock, as on the top of Fourche Mountain, it is much coarser grained than where it has formed narrow

DIKE OF MIAROLITIC ELEOLITE SYENITE IN FOURCHITE.

dikes in the Paleozoic rock. In both cases, however, the rock appears to be completely coarse-crystalline with no tendency whatever towards a porphyritic structure. The structure of both the coarse- and fine-grained dikes may be designated as panidiomorphic granular and may usually be further characterized as being in a high degree miarolitic.

Specific gravity and absorptiveness.—The specific gravity and absorptiveness of this rock as determined on both coarse and fine-grained material gave the following figures :—

	Sp. Gr.	Absorptiveness
Coarse-grained rock.....	2.422	1 : 73
Fine-grained rock.....	2.315	1 : 21.5

Color.—The color of the rock varies greatly with its texture ; in the coarse-grained varieties the color is grayish and often becomes nearly black, in consequence of dark stains of manganese on the surface. The fine-grained rock is, on the other hand, usually of a yellowish color, which is due for the most part to a hydrous oxide of iron formed by the weathering of the iron ores and basic silicates.

Feldspar crystals range from 10 to 20 mm in their greatest diameter and are tabular parallel to the clinopinacoid (010). They have usually been changed to a great extent into kaolin, but, in the coarser specimens, an unaltered center is often visible. Carlsbad twins are very common and are the rule rather than the exception. The feldspars show by their numerous microscopic twinning lamellæ that they are not simple orthoclase crystals, but a microperthitic intergrowth of orthoclase and albite. In many cases albite appears to have formed from the decomposition of the orthoclase and to be present in somewhat fresher crystals than the latter. Cases occur in which both the albite and pericline laws of twinning are in force at the same time.

Biotite occurs in thick, six-sided plates 6 mm or more across. They are bounded by the faces $0P$ (001), $\infty P\infty$ (010), and $-P$ (111).

Amphibole occurs in black lustrous prisms about 3 mm long and of one-fifth that width. Isolated crystals showed under the

microscope the faces ∞P (110), $\infty P\bar{\infty}$ (010) and probably also $P\bar{\infty}$ (011) and $0P$ (001). The yellowish and bluish green pleochroism and the extinction angle of approximately 20° indicate a mineral of the arfvedsonite group.

Sphene and *apatite* occur in large idiomorphic crystals.

Eleolite occurs in the less weathered specimens in somewhat the same form in which it appeared in the eleolite syenite (gray granite). It forms the filling between the feldspar crystals, but instead of being entirely allotriomorphic as in the preceeding cases, it here shows some tendency toward idiomorphism. In cases where it is very plentiful, however, it gives to the rock a decidedly granitic structure. It is generally altered to analcite, and in specimens from near the surface it is entirely wanting, having been altered into soluble compounds and dissolved out by the surface waters.

It seems probable that the coarse-grained dikes which cut the pulaskite were formed by the pressing up of the still fluid magma from the interior through a narrow crack in the already hardened but still hot pulaskite and that thus, to a certain extent, these igneous dikes resemble true pegmatite dikes.* In this way the younger material was warmed from the sides and was allowed to cool slowly and to form the coarse grained, completely crystalline dikes just described. In the case of the narrow, panidiomorphic granular dikes in the Paleozoic shales, the only explanation which appears tenable is that suggested by Brögger (Syenitpegmatitgänge, p. 282) for the Norwegian syenite pegmatite dikes in similar situations, namely; that they were forced from below into cracks in the already heated shales and there cooled slowly, forming a comparatively coarse-grained, uniform panidiomorphic dike.

* According to Brögger (Syenitpegmatitgänge, p. 215), the first author to advance this theory for the formation of pegmatite dikes was Charpentier, in the year 1823. In his "Essai sur la constitution géognostique des Pyrenees" the latter says, "the syenite pegmatite dikes are fissure dikes which were formed immediately or very soon after the solidification of the including granite." (Translated from Brögger, loc. cit., p. 215, who in turn cited from C. F. Naumann, Lehrbuch d. Geognosie, Band II., 1862, p. 232.) They were therefore, "injections of granitic material which, coming from the still liquid granite below, was pressed into the racks of the already solidified granite above,— this is true also of the later-formed masses of the same granite formation,— within whose confines they appear" (Naumann loc. cit., translated from the citation of Brögger, loc. cit.)

b. Miarolitic Quartz Syenite Dikes.*

Before leaving the subject of the feldspathic dike rocks it is necessary to describe two varieties of dikes which may well be designated as quartz syenites. These occur in the form of dikes and independent masses at several points about the Fourche Mountain region. Thus, for example, may be mentioned the large dike on the west side of Fourche Mountain proper (p. 29), which consists of this material, and the loose boulders and other masses on the west bank of the Little Fourche Bayou (pp. 27-28), as well as the fine grained dike found in the quarry of the Little Rock Granite Company (p. 20). From the arrangement of the minerals in this rock and the mode of occurrence of these dikes the rock may be considered aplitic in its structure. These dikes may be divided into two classes which differ from each other principally in the size of the individual crystals and the form in which the quartz appears.

(*1*) *Coarse-grained quartz syenite dikes.*

The dike on the west side of Fourche Mountain proper may be taken as a type of this class.

Macroscopic and Microscopic Characteristics.—The coarse-grained quartz syenite occurs, as already stated, principally in the form of huge boulders and much weathered masses from which it is almost impossible to obtained fresh specimens. The rock is gray or pink in color and characterized at once by the macroscopically easily recognizable quartz grains. Under the microscope it consists of a granular combination of quartz, orthoclase, plagioclase and the remnants of some now indistinguishable basic silicate.

Quartz usually appears in allotriomorphic grains, which often show a tendency to idiomorphism by an indication of a dihexahedral form on the larger grains.

* The term *quartz syenite* is used in place of the name *granite*, in order to express the fact that the rocks in question are genetically associated with the syenite group, and not with true granites. In this connection Brögger remarks (Syenitpegmatitgänge, p. 55, foot note), that he considers that the line between syenite and granite should be determined by the amount of silica which the rock contains and not by the presence or absence of individualized quartz. He places the critical amount of silica at 66 per cent.

On one specimen, a left-handed quartz crystal not exceeding 2 mm in length, the following faces were determined :—

$+R\,x(10\bar{1}1), -R\,x(01\bar{1}1); +3R\,x(30\bar{3}1), +4R\,x(40\bar{4}1),$

$\infty R\,x(10\bar{1}0), +\frac{6P\frac{6}{5}}{4}\,l \quad \tau x(5\bar{1}\bar{6}1), \quad +\frac{4P\frac{4}{3}}{4}\,l\,\tau x(3\bar{1}\bar{4}1).$

This crystal extended into a miarolitic cavity and was of secondary origin, as are most if not all of the idiomorphically bounded crystals. The allotriomorphic crystals are partly primary and partly secondary in their origin.

Under the microscope the crystals extinguish sharply in parallel polarized light and both the double refraction and index refraction are low. In sections which remain dark between crossed nicols during a complete revolution of the stage a black cross without rings appears when the crystal is examined in convergent light. This cross when tested with a mica plate shows the positive character of the double refraction. The quartz is clear and colorless in ordinary light. Large fragments and rounded crystals of orthoclase are sometimes included in it and besides these a great number of liquid inclusions occur. The latter are often arranged in straight lines passing through the crystals in various directions. The inclusions are of two kinds, large irregular ones, which sometimes reach a diameter of 0.1 mm and small ones, which show a crystal form and seldom if ever exceed 0.01 mm in length. Both classes of inclusions usually contain stationary bubbles which are often more than half the size of the cavity. In addition to these, inclusions of minute black rods are quite frequent and they are usually arranged in such a way as to suggest that they are the remnants of some pre-existing mineral. Thus they are often found lying regularly in lines parallel to each other as if representing the cleavage-cracks of some decomposed crystal. These parallel rows of parallel rods are generally terminated at such points as to indicate the position of a bounding face of the crystal making an angle with the direction of the rods. This appearance is heightened by a number of small rods, all still lying in the same direction, but close enough together to form a lateral band along the terminal

plane (Fig. 3). It is probable that these are the skeletons of some basic silicate or of an orthoclase crystal whose substance was gradually substituted by the secondary quartz. These skeletons, if they may be so called, pass through without interruption from one grain of quartz to another, but never into the feldspars.

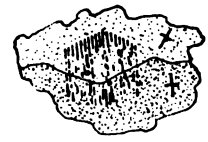


Fig. 3. *Quartz grains (× 20) showing inclusions of black lines forming skeleton of some decomposed mineral.*

The primary and secondary quartz individuals have been described together because in this altered rock it has been impossible to separate them.

Orthoclase appears in idiomorphically bounded crystals where it comes in contact with the primary quartz. It is stout prismatic in form and shows the faces ∞P (110), $\infty P\breve{\infty}$(010), $0P$ (001) and perhaps $+2P\bar{\infty}(20\bar{1})$. It has not been found in fresh crystals but in all cases shows the beginning of kaolinization. Notwithstanding this, however, the microperthitic intergrowth of albite with the orthoclase material is clearly shown by the irregular, patchy and wedge-shaped lamellæ, which have an angle of extinction different from that of the rest of the mineral. The orthoclase contains a great many inclusions, liquid and gaseous as well as solid; these all seem to follow the cleavage cracks, and in the case of the solid particles, they often mark out the skeleton of the feldspar itself as was described above in the case of the skeletons included in the quartz.

Plagioclase has only been observed in a few small crystals which show distinct twinning lamellæ running straight through the crystals. These give extinction angles varying from 10° to 20° with the composition plane, when seen in plates parallel to the base, and hence the crystals are probably close to labradorite in composition. They are, however, distinctly accessory.

The *basic silicates* have usually been altered into a reddish brown, hematite-like substance and are very hard to identify. Some of the sections made up of hematite have nearly right angled corners, and therefore show some evidence of having been at one time pyroxene of some kind. Fresher specimens show that the mineral is ægirite.

Chemical composition.—An analysis of the quartz syenite dike rock was made by the survey, R. N. Brackett, analyst. In order to obtain a fair sample from this coarse-grained, variable rock, a quarter of a kilogram of the freshest material obtainable from the dike on the west side of Fourche Mountain proper, was powdered in a steel mortar, passed through a 40 mesh seive and well mixed. The quantity requisite for an analysis was taken from this material and finely powdered in an agate mortar.

The results obtained from this analysis are as follows:—

Analysis of coarse-grained quartz syenite dike.

SiO_2	64.63
Al_2O_3	18.15
Fe_2O_3	3.05
MnO	1.00
CaO	1.54
MgO	0.50
K_2O	4.79
Na_2O	5.80
H_2O (Ignition)	1.08
Total	100.54

The analysis shows that probably more plagioclase is present than the microscopic investigation indicated. The presence of one per cent of manganese is peculiar. In the next rock described, which is one to which this one is closely related, the amount of manganese contained is much greater. The comparatively high per cent of silica and low water show that the quartz is not all of secondary origin and leached out of the other minerals, but that the rock is constitutionally richer in silica than the eleolite syenite and pulaskite.

There is little doubt but that the eleolite syenite dikes and the quartz syenite dikes, were formed from essentially the same magma and that either by an absorption of silica from the neighboring sedimentary rocks during its intrusion, as in the case of the dike on the west side of the Little Fourche

Bayou,* the quartz syenite became more acid, or else that this increase of silica is due to some as yet unexplained alteration in the magma itself.

(2) *Fine-grained quartz syenite dikes.*

The type of this class of rock is the fine-grained miarolitic dike exposed on the south side of the quarry of the Little Rock Granite Company. The dike has broken through the pulaskite (blue granite) and has followed a crack or joint which dips about 40° to the north. See fig. 4.

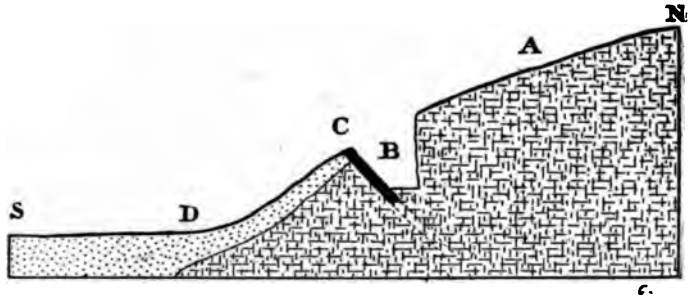


Fig 4.—*Section through the quarry of the Little Rock Granite Company, showing position of quartz syenite dike.*

A. Blue granite (pulaskite). B. Quarry.
C. Fine-grained quartz syenite dike. D. Sand and loam (Pleistocene).

The surface of contact between the two rocks is marked by a decided weathering of the quartz syenite dike and it was only through the kindness of the superintendent of the quarry that fresh material could be obtained. A blast was put into the dike and comparatively fresh rock was blown out.

Structure.—This rock although showing in many cases a miarolitic structure cannot be said to be panidiomorphic, for although occasionaly idiomorphically bounded quartz crystals (probably secondary) occur, this mineral is as a rule allotriomorphic. The structure must therefore be designated as hypidiomorphic granular with a tendency towards panidiomorphism.

Macroscopic and Microscopic characteristics.—The fine-grained quartz syenite dike rock is of a light, almost white color and in all the specimens which have been obtained shows strongly

* Compare the remarks made by Brögger (Syenitpegmatitgänge, p. 129) on a similar increase of silica in the "Nephelinsyenitischen Pegmatitgänge" in the neighborhood of Låven in Norway.

the action of the weather. It seems macroscopically to be made up principally of white feldspar with but few dark colored minerals interspersed through it.

Under the microscope it is seen to consist of orthoclase, plagioclase, quartz, magnetite, hematite and kaolin. The basic silicates have in most cases been completely altered to hematite and other decomposition products.

Orthoclase appears as a white, opaque, generally much kaolinized feldspar, which only rarely shows the characteristic lustre upon the base (001). Under the microscope it is seen to be microperthitic in its structure and to consist of crystals tabular to the clinopinacoid (010) and twinned according to the Carlsbad law. Its characteristics are in all respects very like those found in the coarse-grained variety of this rock. The chemical analysis of the rock indicates that the orthoclase is rich in soda, for where so few varieties of minerals are present in a rock as in this one, and where one predominates as strongly as does the orthoclase in this case, the total analysis approaches quite closely to the analysis of that mineral.

Plagioclase appears very rarely but in comparatively sharp crystals which resemble labradorite.

The *basic silicates* have been mostly altered to oxides of iron and manganese. The high percentage of manganese oxide found by the analysis is very remarkable and indicates that some manganese bisilicate was probably formerly present, but that it is now entirely decomposed and appears only as indistinguishable manganese oxides, either alone or mixed with those of iron.

The analysis of this rock was made by the Survey, R. N. Brackett, analyst, and appears in column I., while column II. contains the analysis of the coarse-grained material which is here repeated in order to bring out the similarity in composition between the two rocks.

It is evident from the appended analyses that, notwithstanding the variations in the quantities of silica, manganese and alumina, the rock are very similar. The manganese of analysis I. possibly replaces some of the alumina and in that case it should be considered as in the form Mn_2O_3. The iron in both analyses is

probably principally in the form of Fe_2O_3 for where so much weathering has taken place as is here observed the iron would be converted into the sesquioxide (Fe_2O_3) or a hydrated form of the same ($2Fe_2O_3+3H_2O$).

The alkalies are quite similar and indicate that the quantities and compositions of the feldspars in the two rocks are also similar. These two rocks are therefore rightly classed ogether in the group of the quartz syenite dike rocks.

Analyses of quartz syenite dike rock.

CONSTITUENTS.	I. Fine-grained rock.	II. Coarse-grained rock.
SiO_2	62.96	64.63
Al_2O_3	13.45	18.15
Fe_2O_3	3.54	3.05
CaO	1.28	1.54
MnO	5.29	1.00
MgO	0.61	0.50
K_2O	5.19	4.79
Na_2O	5.46	5.80
H_2O (Ignition)	2.77	1.08
Total	100.55	100.54

I. Fine-grained quartz syenite dike rock from quarry of Little Rock Granite Company, Fourche Mt., Ark. Anal. by R. N. Brackett.

II. Coarse-grained quartz syenite dike rock from west side of Fourche Mt. proper. Anal. by R. N. Brackett.

D. Porphyritic Border Rock. (Tinguáite).

a. Occurrence.

In the Fourche Mountain region the porphyritic rocks form but an insignificant factor, so far as their distribution is concerned, but, when considered in connection with those from other localities, they show an interesting similarity in structure and occurrence. Specimens of this class of rock have been observed

in but few localities in the neighborhood of Fourche Mountain and even there they are far from being well exposed.

They occur in the immediate neighborhood of the eleolite syenite dikes at the southeast corner of the mountain and cover about 4 hectares (10 acres) of surface, but the weathering which has taken place has been so complete that the character of the rock can only be determined through the occasional occurrence of loose blocks. (See p. 25).

b. Macroscopic and Microscopic Description.

The rock presents a greenish black, greenish gray or purplish appearance and is characterized by small idiomorphic, glassy phenocrysts of orthoclase (sanidine) lying in a macroscopically dense groundmass. The orthoclase is remarkable on account of its extremely tabular form.* It is tabular parallel to the clinopinacoid (010) and its thickness is generally not more than one-tenth its greatest lateral diameter. Thus crystals are commonly found which are 5mm in any direction parallel to the symmetry-plane and not more than 0.5mm in a direction at right angles to it. Even these extremely thin crystals are usually twinned according to the Carlsbad law.

Pyroxene crystals of macroscopic dimensions often appear as minute, greenish prisms and in some cases biotite plates occur, but in other specimens this mineral is entirely wanting.

Under the microscope this rock is seen to be made up of the already enumerated phenocrysts, including also sodalite and eleolite or nepheline, lying in a holocrystalline groundmass, made up of eleolite or nepheline, orthoclase and minute, but idiomorphic pyroxene and amphibole crystals. In some cases these latter minerals have been replaced by chlorite.

Orthoclase is by far the most important mineral among the phenocrysts. It is flat tabular, as has been described, and

* Brögger (Syenitpegmatitgänge, p. 38) describes a "nephelinrhombenporphyr" of a violet-gray color which is characterized by phenocrysts of a greenish gray soda orthoclase and microperthite lying in a dense, nephelinitic groundmass. The characteristic rhombic form of the phenocrysts which give to the Norwegian rock its name does not appear in the Arkansas rock but is replaced by a tabular form, and the rock is considered an eleolite tinguaite. (See Chap. VII, II. B. 4).

resembles sanidine both in its external appearance and in its optic properties. Its double refraction is abnormally low and the optic axis angle, although varying very much for different specimens, is generally quite small and in one case has been found to be zero for white light. The plane of the optic axes has been observed in most cases to lie at right angles to the symmetry-plane, but exceptions to this rule have been found. Carlsbad twins are very common and in one case a twin according to the Baveno law has been observed. While the majority of these feldspars are fresh and undecomposed, some of them show the beginning of kaolinization by becoming opaque in spots and losing their sanidine-like appearance. In a very few cases an indistinct microperthitic structure has been observed, but in general, the crystals appear to be completely homogeneous.

Eleolite or nepheline appears under the microscope in the form of hexagonal sections which remain dark during a complete revolution of the stage, and as weakly polarizing polygonal sections of either quadrangular or irregular forms. In size the hexagons seldom exceed half a millimeter in diameter and are usually somewhat smaller than the sodalite crystals. An indistinct cleavage parallel to the sides of the hexagon is generally visible. The hexagonal sections give no distinct cross, but this is probably due to their extreme thinness and to the weak double refraction exhibited by this mineral. In the sections inclined or parallel to the principal axis the negative character of the double refraction is easily determined by means of a selenite plate. From the general character of these crystals and of those to be described later under the head of "groundmass," it appears that they should be considered as nepheline rather than as eleolite.

Sodalite occurs in comparatively large (0.6mm) phenocrysts whose sections are usually six-sided. They are perfectly fresh and between crossed nicols remain dark during a complete revolution of the microscope-stage. Even by means of a selenite plate no double refraction whatever is detectable. Distinct cleavage in any definite direction is wanting, but a few irregular cracks are visible. Inclusions are numerous and consist prin-

cipally of gas-pores and a few minute crystals of orthoclase and of ægirite.

This mineral was determined to be sodalite from the following facts: the absence of all optic anomalies, and the presence of chlorine and the absence of sulphuric acid in the rock in which it occurs. In proof of this last statement some of this rock was finely powdered and a portion of the powder was heated with nitric acid, and filtered; the filtrate tested with silver nitrate ($AgNO_3$) gave a decided reaction for chlorine. In another portion which was boiled with hydrochloric acid and tested with barium chloride ($BaCl_2$) no formation of barium sulphate was observed, thus excluding the possibility of the presence of haüyne. A portion of the hydrochloric acid solution evaporated to dryness showed numerous small cubes of salt under the microscope. These were probably due, however, rather to the nepheline than to the sodalite, and, in fact, were it not for the chemical tests described above, all of the hexagonal sections would probably have been considered as belonging to the former rather than to the latter mineral.

Pyroxene occurs as phenocrysts some of which are as much as 1mm in length and a quarter of a millimeter in width. They are terminated by the faces ∞P (110), $\infty P\bar{\infty}$ (100), $\infty P\dot{\infty}$ (010) and an acute pyramid, perhaps $6P$ (661), which makes an angle of approximately 12° with the vertical axis. They are of a bright yellowish green color and are quite pleochroitic; the variation in colors is between yellow and bluish green as follows:—

polarized parallel a bluish green.

polarized parallel b olive-green.

polarized parallel c yellow.

The relative absorption is expressed by the formula $a > b > c$. The extinction angle in sections parallel to $\infty P\dot{\infty}$ (010) is about 8°. All these characteristics point toward *ægirite* as the subdivision of the pyroxene group to which this mineral belongs. In some cases a very narrow twin plate occurs lying parallel to the orthopinacoid (100.) In the cases observed this plate was not more than 0.04 of the thickness of the main crystal.

Amphibole, although not appearing as single individuals among the phenocrysts, has been observed surrounding ægirite in a parallel position and in some cases it is again in turn surrounded by the latter.

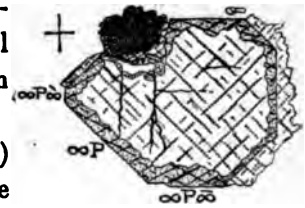


Figure 5. *Ægirite surrounded in parallel intergrowth by amphibole, and then again by ægirite.* (× 60.)

In the accompanying figure (Fig. 5) the cleavage cracks show distinctly the relative positions and physical properties of the two minerals. The amphibole is much more pleochroitic than the ægirite, but in the same sense: thus in the case of amphibole b>a, and b=bluish green; a=yellow; c=(?)*.

The yellow of the amphibole corresponds exactly with that of the ægirite so that, when the section is so situated that the symmetry-planes of both crystals lie parallel to the plane of the lower nicol, no difference in color between the two minerals can be detected. The amphibole resembles very closely that found in some of the preceding rocks and hence it may be assumed to approach arfvedsonite in composition.

Biotite, when it occurs, forms long thin sections which are very pleochroitic, the absorption of light being almost total parallel to the base (001). These crystals are often much corroded and are usually associated with fluorite and apatite.

Titanite crystals occasionally appear, but are by no means common.

The phenocrysts in this rock are usually found scattered singly through the base and are not at all frequent. In the case of the orthoclase it is not uncommon to find two or three crystals close together forming an approximately triangular group, but the ægirite appears, almost without exception, in isolated crystals.

Under the microscope the *groundmass* is seen to consist of a mass of short, rectangular or hexagonal sections of eleolite (nepheline), which are separated from each other by an extremely finely crystalline residual base, which is interspersed with minute prisms of pyroxene and amphibole.

* a of amphibole corresponds in crystallographic position to c of ægirite.
c for the amphibole is undetermined in this case.

The hexagonal prisms of eleolite or nepheline contained in the groundmass are about as wide as they are long and measure as a maximum 0.08mm in diameter. They are somewhat stronger in their double refraction than the phenocrysts, and while those of the older generation are almost free from inclusions of other minerals, those of the younger generation are characterized by large quantities of included basic silicates of the second generation. The eleolite (nepheline) of the groundmass, besides being pierced by the minute, acicular basic silicates, is also often bordered by them and the whole section presents what Bořicky described as a "vegetable cellular structure"*

The basic silicates of the groundmass consist of both pyroxene and amphibole which occur in microscopic, idiomorphic crystals. The pyroxene occurs in slender prisms 0.05 to 0.1mm long and are terminated by rather flat pyramids. They are very pleochroitic and give the absorption relations and color changes of ægirite. The extinction angle in the clinopinacoid (010) is about 5°. The amphibole occurs in thicker prisms which seldom exceed 0.05mm in length. In these the pleochroism is even more decided than in the ægirite but shows a variation between the same colors. Many sections at right angles to the prism zone have been observed in which the characteristic angle of 124°, included between the prism faces as well as the cleavage-cracks parallel to them, was measured. The extinction angle in plates parallel to the clinopinacoid (010) has been measured in a few instances in which it was found to be as much as 20°, but in general it is less than this. This mineral should probably be referred to the arfvedsonite group. Both of the basic silicates are rich in gas and fluid inclusions.

The residual base, which in some cases shows a decided fluidal structure about the phenocrysts and even about the larger of the secondary eleolites (nepheline), is resolvable, under the very highest powers of the microscope, into double refracting bars which have an oblong form and a parallel extinction when examined in polarized light. They are negative in the

* Rosenbusch Physiographie Band II., p. 625. These are shown in Plate V., Figure 3, of the same work.

character of their double refraction and appear as though they might be eleolite (nepheline) of a third generation. Whether any true glass is present between these indistinct crystals is a question which it is difficult to answer with certainty. It is probable, however, that *all of the base is crystalline.*

In some specimens, a groundmass has been observed in which the basic silicates of the second generation do not appear, but are replaced by a brownish or greenish decomposition product of some sort — perhaps chlorite. It shows a spherulitic arrangement of the light colored crystalline components of the groundmass which are probably feldspathic in their character. In such sections the phenocrysts of eleolite (nepheline) or sodalite have weathered to such a degree, that none of the original substance remains, and their former existence can only be inferred from the presence of hexagonal forms filled with calcite and undetermined zeolites. Purple fluorite and small apatite crystals also occur in this rock.

Specimens like those just described are associated with the more distinctly crystalline type from the southeast corner of the Fourche Mountain region and also from near the top of Allis Mountain at the point where the pulaskite comes in contact with the sandy shale. At this point specimens have been found in which one side of the rock is a typical example of pulaskite, while the other side consists of a porphyritic rock, similar to some of the varieties of tinguáite just described, but containing less eleolite (nepheline) and approaching an ægirite tinguáite in composition.

In many respects the rocks of the varieties just described resemble phonolites, but their occurence as border or porphyritic types of the pulaskite or eleolite syenite, places them in the group known as the *tinguáite group.*

Of this group Rosenbusch says (Mikrosk. Physiog. Band. II. p. 627): "A peculiar rock which is not properly classed with the phonolites, but belongs rather with the eleolite syenites, and which cannot be distinguished macroscopically from the former, occurs in dikes associated with the eleolite syenite of Portugal, Brazil, etc. It is characterized by its want of fluidal structure.

It has a hypidiomorphic and occasionally a panidiomorphic granular structure similar to that of aplite." Brögger (Syenitpegmatitgänge, p. 40) describes a similar rock from Norway.

Other varieties of this tinguáitic rock occur in this region, in which eleolite or nepheline are entirely wanting but which probably originally contained a glassy base that has now become cryptocrystalline. Orthoclase or sanidine and ægirite form the only large constituents of the rock and are imbedded in the cryptocrystalline groundmass just mentioned. Professor Rosenbusch kindly examined a specimen of this rock and informed the writer that it presents a great similarity to the rocks from Minas Geraes, Brazil, described by Machado.*

III. PETROGRAPHIC DESCRIPTION OF THE AUGITIC ROCKS.

In the Fourche mountain region these rocks occur, as far as has been observed, only about the southern end of the "cove." They extend for some distance along the eastern side of Allis Mountain from near its southern extremity, as is indicated on map II.

Macroscopically these rocks appear to be of a black, or very dark bluish, or reddish brown color, and are generally characterized by large, distinct augite crystals. The rock is, however, very variable in its appearance, in some cases being very compact and fine grained, and in other cases showing large phenocrysts of augite, or of biotite. These two minerals appear to alternate with each other in forming the phenocrysts, for first one and then the other is found to predominate; yet no genetic distinction between the two rocks can be detected. It is probable, however, that, if the whole top of the hill could be cleared of the immense mass of loose boulders and soil which covers it, these rocks would be found to have been formed from variations of the same magma which have solidified under different physical conditions. However, be that as it may, all that can now be determined is that among these boulders first one type and then the other is found, and

*Beitrag zur Petrographie der südwestlichen Grenze zwischen Minas-Geraës und S. Paulo von J. Machado. Min. u. Petrog. Mitth., Band IX., 1888, p. 347.

that at one point one type predominates, while at another the other is more conspicuous. An attempt has been made to indicate this on the map, but from the nature of the occurrence of these rocks no great reliance can be placed upon such a division.

In many respects these rocks present a great similarity to the dike rocks described by Prof. J. F. Kemp, of Cornell University, in chapters XII. and XIII. of this report. In the description of the individual minerals, etc., reference will be made as far as possible to Kemp's description, in order to avoid unnecessary repetition.

A. Fourchite. *

These rocks are macroscopically as well as microscopically distinctly porphyritic and their structure may now be described as holocrystalline, although it was probably originally hypocrystalline. In general they show large augites, sometimes as much as 25 to 30mm in diameter, imbedded in a dull black groundmass. On weathered surfaces these augites retain their black color, while the groundmass becomes brownish yellow, thus showing more distinctly than ever the porphyritic character of the rock.

Augite crystals make up about 75 per cent of the rock and although in general corresponding very closely to those described by Kemp, they differ from them in some minor characteristics. The twinning, which is rather uncommon in the dike augites, is here of very common occurrence. Crystals made up of two halves, twinned parallel to the orthopinacoid (100) are of fully as frequent, if not more frequent, occurrence than single crystals. The violet color is more marked in these than in the crystals described by Kemp, but the extinction angle in plates parallel to $\infty P\bar{\infty}$ (010) is about the same. One of the most common and at the same time the most striking characteristics of these augites is their beautiful "hour-glass structure." In many

*This rock is named from Fourche Mountain (p. 19, foot note) which received its name from Fourche Bayou, and this in turn was named by the early French explorers *Fourche* on account of its many forks. The name is pronounced in English as in French.

crystals (Fig. 6) this is shown by a complete change of color between crossed nicols, so that, while the sides (*B*) are, for example, a brownish purple the hour-glass shaped ends (*A*) are a brilliant yellow. The zonal structure noted by Kemp appears also in these crystals and is continued through the hour-glass sectors without interruption.

Fig. 6. *Section of augite (11 to 010) in polarized light, showing hour-glass and zonal structure.*
A. Yellow between crossed nicol.
B. Brownish purple between crossed nicol.

Scattered through the rock, and in many cases forming an important constituent of it, are small, irregularly shaped, yellowish, transparent grains, which seldom exceed 0.005 mm in diameter and are often much smaller. They have a high index of refraction and stand out clearly from the general surface of the section, presenting the appearance of small round globules. Since they show a decided double refraction it is probable that they are titanite or leucoxen of secondary generation.

The *groundmass* of even the freshest specimens shows a very complete alteration. It is filled with a dark, reddish brown material, which is a hydrous oxide of iron, in which lighter spots, showing double refraction, are observable. The small highly refracting decomposition grains noted above are also very common. There is, at least at the present time, no glass remaining, but it is probable that the fine grained groundmass solidified originally as a glass and has since been altered to a crystalline mass. If perfectly fresh specimens of this rock could be obtained it is possible that a still glassy base might be found.

An analysis of some of the freshest of this rock was made by the Survey, W. A. Noyes, analyst, and the alkalies were determined by R. N. Brackett.

Analysis of fourchite from Fourche Mountain, Arkansas.

SiO_2	42.03
Al_2O_3	13.60
TiO_2	3.70

Fe_2O_3	7.55
FeO	6.65
FeS_2	0.56
CaO	14.15
MgO	6.41
MnO	trace
K_2O	0.97
Na_2O	1.83
NaCl	0.05
SO_3	0.08
P_2O_5	0.57
H_2O (Ignition)	1.08
Total	99.23

H. Rosenbusch in connection with M. Hunter has lately published a paper entitled "Ueber Monchiquite, ein camptonitisches Ganggestein aus der Gefolgschaft der Eläolithsyenite."* He makes a new group of those older dike rocks which are always intimately connected with the eleolite syenites, and names them *monchiquites* after the Serra de Monchique in southern Portugal where they occur in typical dikes. Rosenbusch considers these as made up of a porphyritic combination of olivine, augite, and a glassy base, with which may be associated either hornblende, or mica, or both these minerals together. The glassy base often includes minute crystals of plagioclase and occasionally of nepheline. Rosenbusch remarks that as yet a separation of these rocks into smaller groups does not seem advisable, but he mentions the follow divisions which might be made :—

Monchiquite,
Biotite monchiquite,
Amphibole monchiquite,
Amphibole biotite monchiquite.

The writer of this report, in connection with Prof. J. F. Kemp and before seeing Professor Rosenbusch's work upon monchiquite, had already described and classified the augitic rocks from the eruptive areas of Arkansas in somewhat the same way, and had proposed certain local names to be applied to them.

* Mineral. und petrograph. Mittheil., Band XI., 1890, p. 446.

Rosenbusch (Physiographie, Band II., p. 821) describes various dikes from the eleolite syenite region near Rio de Janeiro, Brazil, and especially from the Serra de Tinguá under the head of augitite, and mentions their similarity to the dikes described by van Werveke from the foyaite formation in the Serra de Monchique in southern Portugal. The Brazilian dikes are often without olivine and form an olivine-free class of the rock that Rosenbusch calls monchiquite. It is to this class of olivine-free monchiquite that the writer has given the name *fourchite*.

Some specimens of the more important types of fourchite were sent by the writer to Professor Rosenbusch who kindly examined them and expressed his opinion that they belonged to the monchiquite group, but that they were in certain respects different from any specimens that he had seen. In view of these relations these rocks have been included under Rosenbusch's monchiquite group and since they are for the most part either very poor in olivine, or completely free from that mineral, an olivine-free type has been made and cöordinated with the olivine monchiquites. It bears much the same relation to them that augitite does to limburgite in the group of effusive non-feldspathic rocks. The subdivision of this group into biotite, amphibole, and biotite-amphibole types was already completed before Professor Rosenbusch's paper on monchiquite appeared, so that it only remained to group them systematically and in correspondence with the monchiquite rocks. The following scheme of arrangement is suggested:—

Monchiquite Group. (*Rosenbusch*, 1890).

Containing Olivine.	Glassy Base and Minerals: —	Olivine-Free.
Monchiquite (Rosenbusch, 1890)	Augite	Fourchite (J. F. Williams, 1890) [Augitite from Serra de Tinguá (in part). Rosenbusch].
Amphibole monchiquite	Amphibole and augite	Amphibole fourchite.
Biotite monchiquite	Biotite and augite	Ouachitite (Kemp, 1890).
Amphibole biotite monchiquite	Amphibole, biotite and augite	Amphibole ouachitite.

In order to show the close chemical relation which exists

between the fourchite and the true olivine monchiquites, the following analyses which are taken mostly from the Rosenbusch paper are, for the sake of comparison, set side by side with those from Arkansas.

Analyses of monchiquite and fourchite.

CONSTITUENTS.	I. Fourchite, Fourche Mt., Ark.	II. Amphibole monchiquite, Magnet Cove, Ark.	III. Monchiquite, Brazil.	IV. Monchiquite, Brazil.	V. Camptonite, New Hampshire.	VI. Camptonite, Canada.	VII. Pikrite porphyry, Hungary.
SiO_2	42.03	43.50	46.48	43.74	41.94	40.95	40.42
Al_2O_3	13.60	18.06	16.16	14.82	15.36	16.45	28.36 (2°)
TiO_2	3.70	2.10	0.99	2.80	4.15	3.39	.....
Fe_2O_3	17.55	7.52	6.17	2.40	3.27	13.47	.....
FeO	6.65	7.64	6.09	7.52	9.89	.....	.....
FeS_2	0.56	.....	.....	0.10	.....	.....	.....
CaO	14.15	13.39	7.35	10.81	9.47	10.53	11.25
MgO	6.41	3.47	4.02	6.98	5.01	6.10	9.07
MnO	trace.	.....	.....	.....	0.25	0,33 (1°)	.....
K_2O	9.97	1.30	3.08	2.90	0.19	1.28	.....
Na_2O	1.83	2.00	5.85	3.08	5.15	4.00	.....
NaCl	0.05	.....	.....	trace.	.....	.....	.....
SO_3	0.08	.....	.....	.....	.....	.....	.....
P_2O_5	0.57	.....	.....	0.64	.....	0.29	.....
H_2O (direct)	.....	.....	4.27	2.94	3.29	.....	5.22
Ignition	1.08	1.22	.....	.....	.....	3.84	.....
CO_2	.....	.....	0.45	1.50	2.47	.....	1.53
Total	99.23	100.20	100.91	100.23	100.44	100.63	94.85 (3°)
Specific gravity	.....	3.051	2.736	2.914	.....	2.927 to 3.005	.....

(1°) Contains also CoO.

(2°) Contains also Cr_2O_3.

(3°) This analysis foots up to 95.85 but it is given as it appears in Rosenbusch's paper, since the original article by Hussak is not accessible to the writer.

I. Fourchite from Fourche Mt., Ark., by Brackett and Noyes.

II. Amphibole monchiquite from Magnet Cove, Ark., by W. A. Noyes. (Chap. VII., III. A).

III. Monchiquite from Santa Cruz Ry., São Paulo, Brazil, by M. Hunter. (Min. Petr. Mitth., Band XI., 1890, p. 454).

IV. Monchiquite from Rio do Ouro, Serra de Tinguá, Brazil, by P. Jannasch. (ibid. p. 464).

V. Camptonite from New Hampshire, by G. W. Hawes, (Am. Jour. Sci., Series 3, Vol. XVII., 1879, p. 147).

VI. Camptonite from Montreal, Canada, by B. J. Harrington, (N. Jahrb. f. Min., 1883, Band I., p. 248).

VII. "Pikrite porphyry" Steierdorf in the Banat, Hungary, by by E. Hussak, (Verh. d.k.k. geol. Reichsanstalt, 1881, p. 262).

B. Amphibole Ouachitite.

The amphibole ouachitite includes those varieties of augitic rocks which contain phenocrysts of biotite and hornblende, as well as augite, lying in a fine-grained or glassy groundmass. The biotite and augite are easily seen with the naked eye, for they form idiomorphic crystals, often quite large, but not as large as the individuals found in the fourchite just described.

Under the microscope the phenocrysts are seen to lie in an extremely fine-grained, but now completely holocrystalline groundmass which was probably originally a glass.

Augite is by far the most important mineral constituent of the rock, but it would, however, in this case hardly make up 20 per cent of the total mass. The crystals are usually fresh and in all respects essentially the same as those described above (p. 107).

In a few cases perfectly fresh, small augite crystals have been observed filling what is apparently the space which was once occupied by some other mineral. They are radially arranged in the center of the crystals and those about the sides stand at right angles to the edges. It is possible that they take the place of decomposed augite phenocrysts or of olivine.

Hornblende occurs in the rock in much smaller quantities than the augite and forms crystals which seldom exceed 0.4 mm in length. It is easily detected under the microscope by its reddish brown color, strong pleochroism and cleavage-cracks which make an angle of about 124° with each other. It belongs to the variety known as *basaltic hornblende*. The crystals are of a short prismatic habit and, although they have been much

corroded by the magma and are rounded on the corners, they still show that the prism (110) and clinopinacoid (010) faces originally existed. This corrosion has given rise to a peripheral zone which appears to be quite distinct from the rest of the crystal, but still consists of hornblende substance mixed with some magnetite. Inside of the crystals themselves a succession of dark brown concentric bands appear forming a beautiful zonal structure. In some cases twins parallel to the orthopinacoid (100) have been observed. The pleochroism is very strong and is represented by the following formula:—

parallel c=dark reddish brown.
parallel a=yellow.

The hornblende includes magnetite in dust-like grains and occasionally shows liquid inclusions of some size. From its mode of occurrence and general appearance the hornblende is probably to be considered as the oldest constituent of the rock, after the metallic oxides.

Biotite occurs in thin plates which are often quite large. This, like the hornblende, has been strongly acted upon by the magma and shows resorption bands. It is of a reddish brown or yellow color and is very pleochroitic. Its optic characteristics are normal.

The *groundmass* of the rock consists of minute hornblende and augite crystals associated with magnetite in large quantities. The small highly refracting globules already described (page 108) appear here in great numbers. As a background or base for all these minerals, there is found a colorless substance, showing a very low refractive index and a comparatively weak double refraction. When examined between crossed nicols and under a very high power, it is seen to consist of a mass of minute crystals which are negative in their double refraction and have small angles of extinction. Their boundaries cannot be definitely determined, but the direction of the greatest elongation and of the indistinct cleavage-cracks has been taken as the probable direction of the principal axis. It would appear from these characteristics that some feldspathic mineral is present. No twinning lamellæ were observed, but it is probable

from the lath-like shape of the crystals that the feldspar is a plagioclase which was formed by the devitrification of an original glass. The occurrence of hornblende and of biotite and the possible presence of a glassy base indicate that a rock corresponding to the third variety of Rosenbusch's monchiquite group (loc. cit. p. 450), the biotite amphibole monchiquite, but without olivine, is under consideration. This would, therefore, according to the nomenclature adopted for these rocks, be an amphibole biotite fourchite or, more simply expressed, an amphibole ouachitite.

C. Monchiquite (?).

Some specimens occur at the south end of the "trap" area on Allis Mountain, which, although much weathered, still indicate that they belong to a somewhat different type from those rocks already described. These rocks are remarkable not only on account of the peculiar and rather uncommon pseudomorphs of mica after augite which they contain, but also on account of the large quantities of the already described globular titaniferous mineral which, in this case, sometimes attains a diameter of 0.01mm and is more sharply defined than in the preceding rocks.

Pseudomorphs of mica after augite frequently occur in this rock and are even macroscopically easily recognizable. The crystals are 1 to 1.5mm in length and show the original faces ∞P (110), $\infty P\bar{\infty}$ (100), $\infty P\check{\infty}$ (010), $0P$ (001), $-P$(111) and also some dome faces in the ortho-zone. In a few instances the central portion of the crystal remains undecomposed, but in most cases the alteration is complete throughout the whole crystal. In those cases where the central portion of the crystal still remains unaltered it is seen to have been completely freed from iron, so that it appears colorless and is absolutely non-pleochroitic. Where the alteration has taken place completely the crystal is entirely made up of small, irregularly grouped mica plates which seldom exceed 0.05mm in diameter. These plates are of a reddish brown color and may, perhaps, be *rubellite*, although it appears more probable that they are *biotite* somewhat

stained with iron oxide. G. von Richthofen* describes pseudomorphs of rubellite after augite, from the tufa formations of Alpe Ciaplaja, on Monte Creppa, and from other points of southern Tyrol. The Tyrolese pseudomorphs show that the alteration began at many points in the interior of the crystals and formed nests of reddish mica plates which, in some cases, increased in size and numbers so as to include the whole crystal. Blum mentions mica pseudomorphs after augite from the Fassa Valley, in southern Tyrol, Austria,† and from Monroe, Orange county, N. Y.,‡ and Tschermak describes such from teschenitic rocks‖.

In the pseudomorphs from the Arkansas rocks the alteration appears to have taken place from the outside and to have worked in along the cracks. The undecomposed parts, when such exist, are found uniformly at the centre of the crystal, and are often cut through by cleavage cracks along the edges of which some alteration has taken place. The mica which is, as has been stated, probably a stained biotite occurs in small, thick plates absolutely without parallel arrangement of any kind. These plates are very pleochroitic; the color variation being from a very light red or straw color to a deep brown. The optic axis angle is small.

In this decomposed rock there appear indications of the alteration of some mineral, probably olivine, to serpentine, but the forms are not such that they can be definitely determined.

In addition to these phenocrysts there have been observed in the groundmass, which consists principally of augite needles and the already mentioned globular titaniferous mineral (p. 108), some feldspathic minerals which are evidently the devitrification products of an original glass. These feldspar (?) crystals are of two varieties, twinned and simple, and both of them appear as very slender, lath-like individuals not over 0.07mm in length.

The rock evidently belongs to the monchiquite group, but whether to the olivine or olivine-free variety is uncertain. It is

* G. von Richthofen in the Wiener Akad. Ber. Band XXVII., 1858, p. 335, and in Blum's Pseudomorphosen, Band III., p. 96. Cited after J. Roth's Chemische Geologie, Band I., p. 340.

† Pseudomorphosen. Blum. Band I., p. 31. Cited after Roth.

‡ Ibid. Band III., p. 93. Cited after Roth.

‖ Porphyrgesteine Oesterreichs, G. Tschermak, p. 264. Cited after Roth.

probable, however, that it may be more properly considered as belonging to the former variety and as forming a true monchiquite in the more restricted sense of the term.

From the same locality other altered rocks occur which differ from these only in the fact that the augite crystals have been altered to chlorite instead of mica. The chlorite appears in small six-sided plates seldom more than 0.04mm in diameter. It is of a beautiful green color, and in plates cut at right angles to the cleavage-planes it shows a comparatively strong pleochroism, with an alteration in color from yellow (||c) to green (||a or b.) When observed in plates parallel to the cleavage it appears dark green and isotropic and in convergent light shows no distinct cross. Between crossed nicols the polarization colors appear higher than those usually described for this mineral.

The rock is of a generally greenish color with darker green spots where the chlorite pseudomorphs occur.

Upon reviewing the above descriptions it is evident that, although some minor variations exist, the rocks belong to one and the same group. It seems better therefore to unite them under the name of *fourchite*, with a clear understanding that the varieties described are present, but that, owing to the poor exposures and to the weathered condition of the rock, it is absolutely impossible to define the limits of the various types, or to study their mutual genetic relations.

IV. CONTACT ROCKS.

In the Fourche Mountain region contact rocks are not very numerous nor easily studied. In a few cases specimens of contact shale have been found which show a very decided metamorphism and an almost complete alteration into a crystalline rock. Such a metamorphism has usually taken place only where the sedimentary rocks are in direct contact with the larger masses of syenite, for in cases where small dikes cut through the Paleozoic shales little or no alteration exists.

At a point near the junction of Fourche and Ermentraudt Mountains on the east side of the ridge the syenite is found in

direct contact with the shale. It is seen to have induced in the latter small (0.5 to 1mm) irregularly bounded feldspar crystals, which now form the main mass of the rock. These feldspars are often twinned according to the Carlsbad law, but show by their undulatory extinction and peculiar microstructure that they are of secondary origin. They are, almost without exception, filled with minute, black grains which are presumably magnetite. These are scattered through the crystals without any regular system of arrangement and without any special reference to the crystallographic form of the individuals in which they occur. In a few cases larger crystals of feldspar have been observed, and when such occur, they are seen to have a more perfect crystallographic form than the smaller ones. It is probable that the larger crystals were formed first and were therefore in a position to rearrange the ingredients of the shale and those obtained from the igneous rock more freely than the smaller crystals which followed them. They may be considered as the "phenocrysts" of the metamorphic rock.

Mica crystals, often very fragmental and distorted, occur very frequently. They are of a greenish yellow color and show strong pleochroism. When the cleavage-planes stand at right angles to the plane of the lower nicol the color is a light yellow with a faint greenish tinge, and in some cases the crystals are almost colorless. At right angles to this position they are almost or entirely black and show a correspondingly complete absorption of light. It is probable from these facts that this mica is a *biotite*. The irregularity in the shape of the plates and flakes shows that it was not entirely unhindered in its crystallization, but its comparatively large size (1 to 1.5mm in diameter) indicates that it was one of the earlier and more freely formed materials.

Small fragments of some green mineral resembling ægirite in their appearance and behavior in polarized light occur in this rock and certainly constitute some member of the pyroxene group.

A thin section of this rock is seen under the microscope to be completely studded with small black specks of magnetite

which are often rounded, and only occasionally show any indications of crystal form. Hematite and limonite also appear in irregular masses, the former often taking the shape of thin plates, while the latter is naturally without definite crystal form.

Six inches (0.15m) away from the contact, as a rule, the shale shows very little metamorphism, and it is only here and there that any indication of a secondary crystallization can be detected.

In some cases the syenite is seen to penetrate the sedimentary rocks for a short distance from the contact, thus forming alternate bands of igneous and metamorphosed rock. In one case the igneous rock is found to make up more than half of the specimen, while the metamorphosed rock occurs in the form of narrow intermediate bands presenting a semi-fluidal appearance. Under the microscope these bands are seen to be made up of minute, allotriomorphic feldspar, magnetite and hematite crystals and a few flakes of reddish brown mica.

A peculiar feature of the rocks near the contact, and one which is characteristic of both the intrusive rocks, as well as of the metamorphosed sedimentaries, is the dark blue or black stain with which these rocks are quickly covered when left exposed to the air and rain for a few days. (See page 22). The igneous rocks seem to show the color even more distinctly than the metamorphosed sedimentary deposits, and it has been observed that when the former are heated before a blast-lamp they they give off sulphur enough to burn with a blue flame for some time, even after the source of heat has been removed. The dark blue stain appears to be connected in some way with the large amount of sulphur present, for after the rock has been heated for a time and the sulphur driven off it assumes a reddish color. It is possible that the stain is due to a mixture of sulphur (S) and ferrous sulphide (FeS) which was temporarily formed as an intermediate stage in the alteration of pyrite (FeS_2) to ferric oxide (Fe_2O_3).

East of the southern end of Ermentraudt Mountain (section 35, S. W. of S. W.) and on the eastern end of the southern part of Allis Mountain (section 34, N. W. quarter) black hornstone-like

rocks occur which were formed by the metamorphism of the black shale of that region. Under the microscope these rocks show a confused crystalline structure produced by the formation of small flakes of mica, and the differentiation of the substance of the shale into a mass of minute feldspar needles. The Paleozoic rock which forms a small area in section 36 [on center line 1,000 ft. (305m) west of center] (see page 24) and is some distance from the igneous rock contains well formed, tabular feldspar crystals which sometimes attain a diameter of 2mm. The rock in which they occur is an arenaceous shale and occasionally contains minute ægirite crystals as well as feldspars.

In many cases the sedimentary rock is scarcely altered, even where it occurs very close to the igneous rocks. It is evident, therefore, that something more than mere proximity to an igneous mass is necessary to form crystalline metamorphic rocks.

V. GENETIC RELATIONS OF THE VARIOUS KINDS OF SYENITE TO EACH OTHER AND TO THE ADJACENT SEDIMENTARY ROCKS.

The relations of the various kinds of syenite found in the Fourche Mountain region to each other and to the under- and overlying rocks are not as simple as they at first sight appear.

It seems probable, however, both from petrographic and chemical considerations, as well as from their geologic positions, that the syenitic rocks of the Fourche Mountain region are very closely related to each other and that they may be considered as derived from one and the same magma which, on account of the various conditions under which it cooled, has formed the different kinds of rock occurring in the region.

It is evident from its coarseness and entire lack of porphyritic structure that the gray granite (eleolite syenite) cooled under pressure as a true intratelluric rock. The blue granite (pulaskite), on the other hand, is decidedly trachytic or porphyritic in its structure and cooling much more rapidly formed a dike rock. It is easy to conceive of these rocks, as a whole, being forced up through a break in the overlying rocks, and of that portion which came up into the crack itself as being cooled

more quickly than the mass which remained lower down and was protected against loss of heat by the overlying rocks. These overlying sedimentary rocks soon became heated through and acted as covering, transmitting heat slowly, and allowing the underlying igneous masses to cool gradually and to form true intratelluric rocks*.

It seems more than probable that the overlying strata in the Fourche Mountain region were comparatively thin, for it is evident from many considerations that comparatively little erosion of the Paleozoic rock has taken place since the igneous rocks were intruded. The accompanying section, which is of

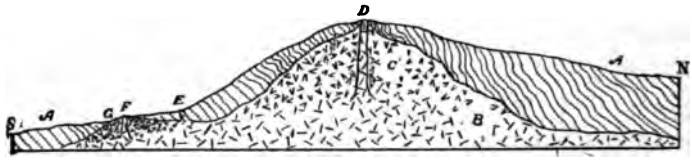


Figure 7. *Ideal section through a part of the Fourche Mountain region when formed.*
A. Paleozoic rock.
B. Gray granite (eleolite syenite)
C. Blue granite (pulaskite.)
D. Miarolitic eleolite syenite dike in Pulaskite.
E. Miarolitic eleolite syenite dike in Paleozoic rock.
F. Brown granite (eleolite syenite dike rock.)
G. Eleolite tinguäite.

course somewhat idealized, but which is founded upon the relations actually observed in the region near the southeast corner of the mountain, shows the probable relations of the various rocks to each other.

(*A.*) represents the overlying shales of Paleozoic age, which dip sharply to the north and form part of the great anticlinal fold described by Mr. L. S. Griswold in Vol. III of the annual report of the Geological Survey of Arkansas for 1890†.

(*B.*) represents the mass of underlying intratelluric gray

* The subject of the thickness of overlying rocks necessary to produce the formation of holocrystalline granitic rocks has been discussed by Brögger (Syenitpegmatitgänge, p. 224.) He comments upon the theories advanced by J. Lehmann [Granulitgebirge, p. 55. Cited after Brögger. (Syenitpegmatitgänge, p. 225.)] and others. Brögger's conclusions are to the effect that a few hundred feet of overlying rock suffice for a covering which will make the igneous rocks below completely *intratelluric* in their character.

† It may here be stated that it is extremely probable that the weakness produced in the strata by this folding was taken advantage of by the intrusive rocks in forcing their way into the overlying sedimentary formation.

granite (eleolite syenite) which at one point forced its way up through the sedimentary beds forming the semi-porphyritic mass of blue granite (pulaskite) (*C*) in the interior of which the gray rock would be found could the ridge be penetrated to a sufficient depth.

(*C*.) represents the blue granite (pulaskite.) It is evident that this blue variety cooled more quickly than the gray rock and therefore assumed a more porphyritic structure. When this blue granite (pulaskite) cooled, it cracked, on account of the unequal contraction of the outside and the inside and allowed the panidiomorphic granular dike rock (*D*) to appear. This latter consists, therefore, of some of the original syenite magma (*B*) which, on being pressed up through the still hot, but already congealed blue granite (pulaskite) solidified very slowly as a coarse-grained, panidiomorphic dike. It is probable that a not inconsiderable space of time intervened between the intrusion of the blue granite (pulaskite) and the formation of the coarse aplitic dikes. In the case of the dike (*E*) the conditions were somewhat different, for here the coarse-grained dike comes up through the overlying Paleozoic rocks and is still panidiomorphic in its character. The only explanation of this which can be offered, is that suggested by Brögger for similar cases (Syenitpegmatitgänge, p. 231), in which it is assumed that the Paleozoic rock was completely heated through before the injection of the igneous rock. In the case of the tinguáitic rock (*G*) near the same region (southeast of the mountain) it may be assumed that its character is due to the thin cover of overlying sedimentary rock in that particular region. This condition would be in complete accord with the high heating of the neighboring Paleozoic rock, required for the formation of the coarse-grained dike just described, and would fit the case equally well if the porphyritic or tinguáitic rock should prove to be, in part, a metamorphosed shale and not an intrusive rock. The other dike (*F*) of brown granite (eleolite syenite dike rock) which appears in this region and which has a hypidiomorphic granular structure, would then be considered as the filling of a crack by a syenitic material which to some extent resembles both the blue

and gray granite and which was intruded at the same time they were.

All these considerations point to a comparatively thicker (still actually quite thin) covering of Paleozoic rock over the larger part of the region and to a thinner layer over the southeastern part of the area. As has already been remarked, the main topographic features of the county, so far as the Paleozoic rocks are concerned, are considered by the writer to have been approximately as they are now; all the folding and bending had been completed and a large part of the erosion had been accomplished. Since the intrusion of the igneous rocks the overlying Paleozoic rocks which served as a cover have been eroded, and the Tertiary rocks have been deposited and also carried away again, leaving only here and there traces to show where they once were.

The occurrence of panidiomorphic syenite dikes cutting the "trap" (fourchite) and allied rocks, as well as the adjacent Paleozoic shales near the south end of Allis Mountain can only be explained by assuming that the fourchite is older than all the syenites, or that it was intruded after the blue and gray granites were formed but before the coarse-grained miarolitic dikes were intruded. In the first case the augitic rock must either have retained some of its original heat, or else, like the shales, must have been heated by the neighboring masses of syenite before the younger syenitic dikes were intruded. If the fourchite is younger than the blue syenite it would naturally retain enough heat to make the intruding dikes of syenitic material coarse-grained.

When the rocks of the Fourche Mountain region are compared with those from Saline county, a strong likeness is found to exist between the fourchite of the Fourche Mountain region and the dikes of black rock which cut the syenite in Saline county. Without anticipitating too much, the Saline county syenites may be said to resemble very closely the gray granite (eleolite syenite) of the Fourche Mountain region, and hence if the two are considered identical the fact that the former are cut by dikes similar to fourchite (including true monchiquite)

would suggest that in the Fourchite Mountain region also the fourchite is younger than the gray granite (eleolite syenite). *

If the sequence of the rocks of the Fourche Mountain region suggested above be correct the rocks of this region were formed in the following order:—

First: The magma from which the gray and blue granites (eleolite syenite and pulaskite) and the dikes belonging to them were formed was forced up from below and cooled as described (page 120).

Second: The fourchite was intruded.

Third: The pegmatitic and miarolitic dikes of syenitic material were intruded before the earlier rocks had entirely cooled.

This is the probable sequence of the formation of the rocks of Fourche Mountain as far as the igneous rocks themselves are concerned. Their relations to the sedimentary rocks are such that little can be learned concerning the date of their intrusion, but by a comparison of the facts known about the age of the rocks of the other regions (chaps. V., VIII. and IX.) with those known about this region, it is probable that the formation of these rocks took place during the latter part of the Cretaceous or the early part of the Tertiary period.

The want of tufa, ashes, scoria, etc., indicates that these rocks are intrusive and not effusive in their character, but the same considerations and limitations as those suggested for the Magnet Cove rocks (chap. VIII.) must be regarded here.

Since the formation of the syenites the Fourche Mountain

* The other hypothesis which has, however, little but negative evidence to support it, is that the fourchite is older than all the syenite masses and that after its intrusion they were formed in the manner and the order detailed above. The only points in favor of this hypothesis are the fact that no fourchite dikes have been found in the blue or gray granite of the Fourche Mountain region, and the consideration that only one change from a basic to an acid magma need be assumed, while in the accepted hypothesis a change from an acid to a basic and then from the basic back again to an acid magma must be assumed in order to satisfy the facts observed regarding the mutual relations of these rocks.

The first of these points is of but little consequence since only a small area of gray granite (eleolite syenite) in which fourchite dikes might occur is exposed. If dikes of fourchite occur in the blue granite (pulaskite) it is probable that they are covered up by blocks weathered syenite and are invisible. In regard to the second consideration it may be stated that the change from an acid magma to a more basic one is the natural order of events and that the inversion of this order is contrary to the general law of sequence of such rocks.

region has been again partially submerged beneath the ocean. During Tertiary times a deposit of highly ferruginous sandstone was formed, and interbedded with this there is a deposit of bauxite.* That the origin of this material is connected in some way with the syenite is beyond doubt for it is only found in comparatively close proximity to it in both the Fourche Mountain and the Saline county regions.

Two suggestions present themselves to account for the presence of this material, neither one of which seems completely satisfactory. The first, and it seems to the writer the less probable of the two, is that the bauxite is formed by the decomposition of a bed of clastic material which was derived principally from the syenite. In this way it might easily occur interbedded with the Tertiary rocks as indeed it has been found, but it would be natural to expect to find masses of undecomposed syenite scattered through it. This, however, is not the case and beyond a few angular pieces of Paleozoic sandstone no foreign material has been found in it.

In order to make such a theory as this tenable two transformations at least must be assumed so as to account for the material as at present found. It is well known that the the common decomposition product of syenite is kaolin ($Al_2O_3. 2SiO_2 + 2H_2O$) but in the case of the bauxite little or no silica is present and the rock has a chemical composition represented approximately by the formula $(Al, Fe)_2 O (HO)_4$, in which the aluminium and iron may replace each other in all proportions. In order, therefore, to produce such a compound, some agent capable of extracting the silica completely from the decomposed syenite must be assumed. The only available agent which could act in this way is a strong alkaline solution and it is probable that such a solution would, at the same time, act very energetically upon the alumina itself.

As the undecomposed syenite contains very little iron some extraneous source of this element must also be assumed and its presence in quantities amounting in some cases to 50 per cent must be explained by the infiltration of ferruginous material.

* See Vol. I. of the annual report of the Geol. Survey of Ark. for 1889.

The bauxite of the Westerwald and in the neighborhood of Giessen, Germany, has been stated to be due to the weathering of basalt while that from other localities occurs as oölitic grains in calcite. In some cases where the Fourche Mountain syenite has partially broken down to kaolin, an oölitic or pisolitic structure exists.

The second and more plausible theory is that the bauxite is the result of hot spring action.

The water of the Tertiary sea penetrated to the still highly heated igneous rocks and under the influence of the high pressure and temperature dissolved the constituents of the granites and the neighboring rocks, but in very different proportions. These substances were brought to the surface in solution and the water emerged in the form of hot springs, surcharged with dissolved matter. As soon as the pressure was removed and the temperature was reduced the excess of dissolved matter began to precipitate in the form of a basic hydrate of aluminium and iron, while the more soluble salts of the alkalies were still held in solution. The continual bubbling and movement of the water would result in the formation of concretions about some small nuclei as is the case with the calcareous Carlsbad sprüdelstein, and by the solidification of these nodules into a single mass the bauxite rock would be formed. Were the material carbonate of lime which is easily soluble in water containing carbonic acid instead of the practically insoluble hydrate of alumina there would be no trouble whatever in explaining both its occurrence and its form by some such hypothesis as that suggested.

The kaolin deposits near Fourche Mountain are principally derived from the decay of the syenite *in situ*. In regard to these deposits, their distribution and extent, the State Geologist makes a report in Vol. I., of the annual report of the Geological Survey of Arkansas for 1889, and to this the reader is referred for further information on this subject.

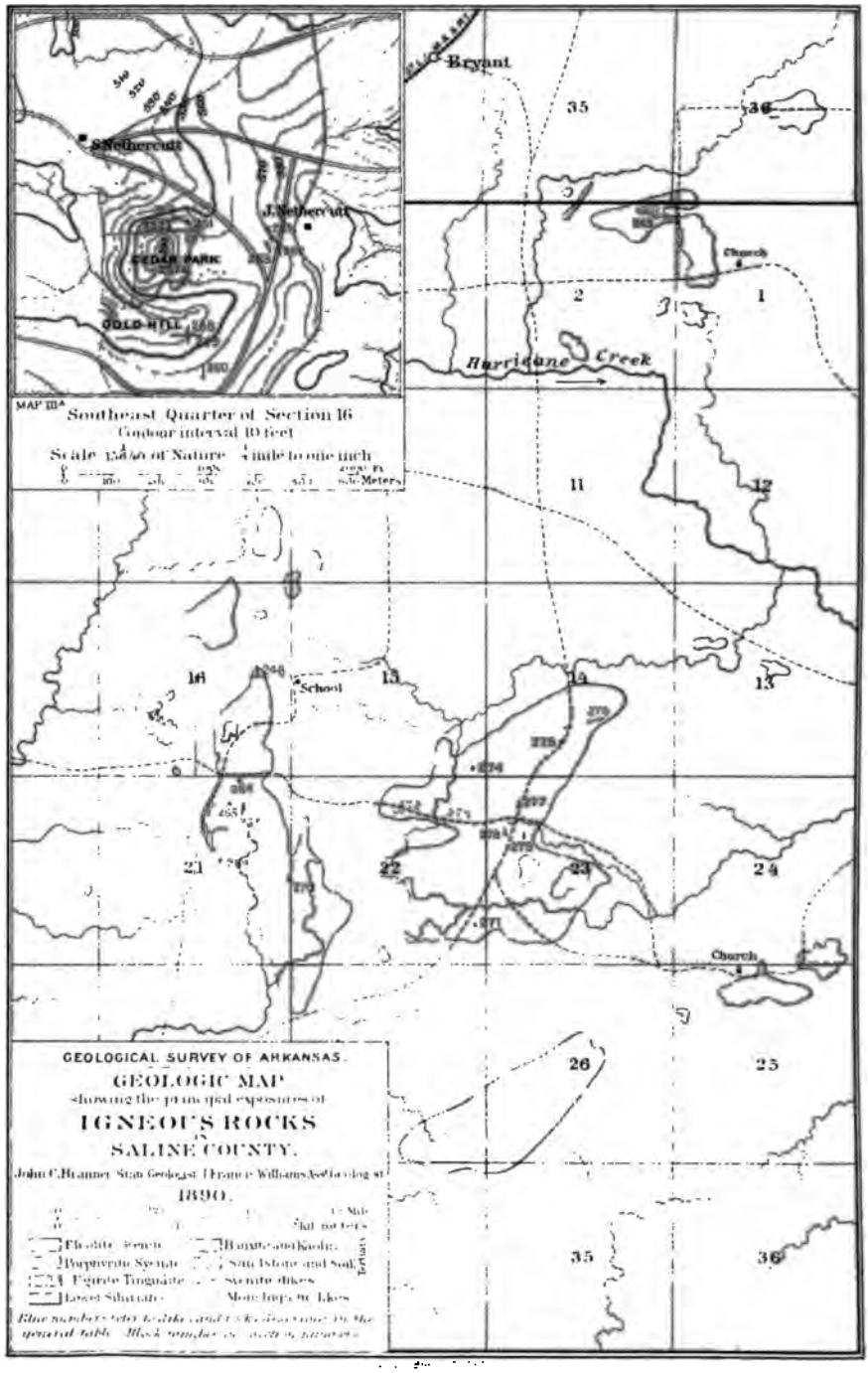
CHAPTER V.

Distribution and Petrographic Character of the Igneous Rocks of the Saline County Region.

I. Distribution.
II. Special Petrographic Literature.
III. Petrographic Description of Feldspathic rocks.
  A. Eleolite Syenite (Gray Granite).
    1. Orthoclastic Eleolite Syenite.
      a. Physical Properties.
      b. Mineralogic and Microscopic Examination.
    2. Plagioclastic Eleolite Syenite.
  B. Porphyritic Syenite.
  C. Syenitic Dike Rocks.
    1. Eleolite Syenite Pegmatite Dikes.
    2. Porphyritic Dikes.
      a. Ægirite Tinguáite.
      b. Eleolite Porphyry.
  D. Porphyritic Border Rock (Ægirite Tinguáite).
IV. Petrographic Description of the Augitic Rocks.
  A. Amphibole Monchiquite.
  B. Monchiquite.
V. Contact Rocks.
VI. Relation of the Igneous Rocks of Saline County to each other and to the Adjacent Sedimentary Rocks.

I. DISTRIBUTION.

On referring to map III., it will be seen that the "crystalline rocks" of Owen cover many hundred acres in Saline county. The areas in which they appear are all bordered by Tertiary and Pleistocene deposits and it is more than probable that the syenite forms a continuous mass


Bryant
S.Nethercutt
J.Nethercutt
CEDAR PARK
GOLD HILL
Hurricane Creek
Church
School
Church
MAP III A
Southeast Quarter of Section 16
Contour interval 10 feet
Scale 1/2640 of Nature 4 mile to one inch
GEOLOGICAL SURVEY OF ARKANSAS.
GEOLOGIC MAP
showing the principal exposures of
IGNEOUS ROCKS
SALINE COUNTY.
1890.

beneath this thin superficial layer. The syenite often appears as loose blocks scattered over the sandy soil where no solid masses of rock can be found. Such areas, where the soil is to a great extent formed by the disintegration of syenite, are represented on the map by small red dots over the Tertiary yellow.

The general topography of the country is uninteresting. In traveling from Benton to the syenite region, a distance of about 5 miles (8km), it is possible to keep along the tops of the Tertiary ridges for the greater part of the way, only now and then descending to cross from one to another through the low boggy bottoms which lie between them. None of these ridges rise more than one hundred and fifty feet (45m) above the general level of the country. The hills are heavily timbered with pine and post-oak but the soil is thin and sandy and yields but little return to cultivation.

The igneous rock appears, for the most part, in large, flat, horizontal or slightly sloping areas of smooth rock. Where enough soil has collected on these areas to allow of it, they are usually covered with a dense growth of cedars. It is, however, quite common to find open spaces of bare rock an acre or more in extent completely surrounded by a belt of trees; such openings are known as "cedar glades." In these glades the surface of the rock is generally smooth, and it is not an uncommon thing to find spaces containing several thousand square feet completely free from cracks or joints of any kind so that blocks of stone of almost unlimited dimensions could be quarried from them.

At only three points in this area do the Paleozoic rocks appear and in all of these cases they are more or less metamorphosed. The most important of these Paleozoic masses is known as Cedar Park * and contains about thirty acres (12 hectares). It consists of a greenish shale which is much altered and disturbed. The shale dips about 80° north, but it is so broken that this determination is very uncertain. The hill is covered with a luxuriant growth of

* Township 2 S., range 14 W., southeast quarter of section 16. See map III. A.

cedars and presents a very striking appearance when compared with the bare igneous rocks which immediately surround it. It is cut by several dikes of both syenite and monchiquite, which will be more minutely described later.

About fifty yards (45m) southwest of Cedar Park, across a deep cut in the igneous rock, another small mass of sedimentary rock, known as "Gold Hill," occurs. It is not more than one or two acres (0.4 to 0.8 hectares) in extent and is surrounded on three sides by syenite, but is bounded on the fourth, the southwest side, by Tertiary sandstone. It is probable that this hill once formed a part of the Cedar Park area and was separated from it by erosion.

The third point* where the Paleozoic rocks appear is just south of the north line of section 21 and lies due south of the Cedar Park region. The rock in this case is an included block of shale about 6′×9′ (1.8×2.7m.) and has somewhat the form of a flat-iron. (Fig. 8).

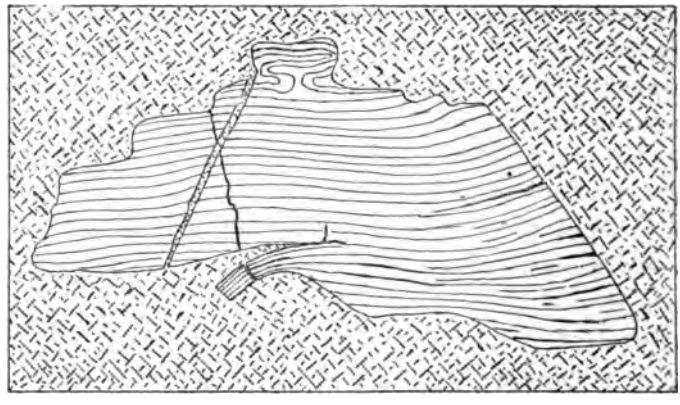


Fig. 8. *Mass of Paleozoic rock included in eleolite syenite.* Scale—1:36.

The shale shows its original stratification very distinctly, and in some places syenite has forced itself in between the layers of the sedimentary rock in such a manner as to curve them away from the main mass. In other places it has filled

* The thanks of the Survey are due to Mr. Solomon Nethercutt, the owner of the greater part of section 16, for his help in finding this and many other localities which will be mentioned in the course of this chapter, as well as for his assistance and guidance in obtaining the data for the small topographic map of the region. (Map III. A.)

cracks which cut across the original stratification planes.

With these exceptions the syenite is everywhere bounded by overlying sandy deposits.

As has been stated, the main portion of the syenite consists of a gray variety of rock which resembles very closely the gray granite (eleolite syenite) of Fourche Mountain and only in a few places does anything which approaches the blue granite (pulaskite) appear. The principal point at which the latter rock is found is in the northwest of the northwest quarter of section 23, where it forms several narrow mounds of loose blocks, 20 feet (6m) high by 100 feet (30m) wide and 500 to 1000 feet (150 to 300m) long. This rock weathers into angular blocks and resembles macroscopically in every way the blue granite (pulaskite) of Fourche Mountain. It is designated in this report as porphyritic syenite.

In the southeast quarter of section 14* rocks occur which show an inclination toward the theralite group. It is evident that they constitute a large mass of rock in that region and that, like the light colored eleolite syenite, they form large, flat surfaces of solid, unbroken rock. Macroscopically they are indistinguishable from the eleolite syenite so that, without making thin sections of all the rocks in the neighborhood, it is impossible to judge of their extent.

In order to avoid a detailed and uninteresting description of the igneous area the reader is referred directly to map III. On this map the principal masses of igneous rock are indicated by special colors; and the narrow dikes of intrusive rock of both the monchiquitic and syenitic types are numbered and are referred to in the general table. (Chapter XIII.)

II. SPECIAL PETROGRAPHIC LITERATURE.

The only mention of the occurrence of the large masses of igneous rocks in Saline county are notices by W.

* On and near Mrs. Monlux's property.

9 Geological; Vol. ii., 1860.

B. Powell, D. D. Owen and F. L. Harvey, in their already quoted works.

Powell* mentions having heard of this region and having seen hand specimens from the locality.

Owen, † says: "As in Pulaski and Hot Spring counties, we have, in Saline, small areas occupied by crystalline rocks. One of the principal protrusions of granite in this county is in Township 2 S., Range 14 W. Some of this granite is quite porphyritic, the feldspar crystals standing out in prominent relief on the weathered surface. Some of this granite has a graphic appearance, and there are disseminated through it crystals of hornblende and (schorlamite?). Some of this rock looks very much like zircon granite."

Harvey ‡ remarks, "Typical granite occurs in Fourche Cove, Saline county, and Magnet Cove."

III. PETROGRAPHIC DESCRIPTION OF FELDSPATHIC ROCKS.

A. Eleolite Syenite.

1. Orthoclastic Eleolite Syenite.

a. Physical Properties.

Use.—The orthoclastic eleolite syenite occurs in large masses and has been quarried to some extent. It is considerably used in the immediate neighborhood and limited quantities of it have been shipped away. It is probable were better facilities for transportation afforded that it would become an important stone for architectural purposes. The rock takes a good polish, as is shown by a small headstone made of this material which was exhibited at the Little Rock Exposition of 1887, and which is now in one of the stone-cutting establishments of that city.

Color and structure.—It is a light gray rock with occasionally a pinkish or buff tinge given it by the flesh

* Geological Report on Fourche Cove, etc., p. 6.

† Second Report of a Geological Reconnoissance of Arkansas, etc., p. 107.

‡ Minerals and Rocks of Arkansas, p. 31.

colored or yellowish eleolite crystals. In general it is coarse grained but it varies extremely in this regard. It presents macroscopically a trachytic structure, which occasionally inclines towards a porphyritic structure on account of a diminution in the size of all the constituents except the feldspar.

The color and the general arrangement of the constituents of this rock are shown by a chromo-lithograph of a polished surface (see plate 1, frontispiece).

A pegmatitic appearance is very common and is due to the peculiar arrangement of the large tabular feldspars. Feldspar and eleolite are easily recognized macroscopically but the basic silicates present are usually too small to be identified by the naked eye.

Strength.—The resistance to crushing exhibited by blocks of this stone which, however, were not perfectly fresh, was determined by tests precisely similar to those made on the other syenites. (See page 42 seq.) The results are as follows:—

Pressure* per square inch under which cube crumbled..... 20,500 lbs.

Corresponding pressure in 2-inch cube calculated by cubic parabola formula..... 22, 350 "

From this it appears that this rock is about as strong as the strongest true granite. Under the chisel it works much more easily than most of the granites and might, therefore, be used to advantage for carved work for interior decoration. Exposed to the weather this rock does not appear to stand very well. The refuse chips from some blocks quarried ten or fifteen years ago for building chimneys and making door-steps have been left exposed to the weather in the open pits where they were first broken. These show, almost without exception, a decided tendency to crumble on the edges and when broken with a hammer do not yield sound specimens.

* This test like those upon the Fourche Mountain rock was made upon a cube less than two inches on an edge. The figures obtained from the test before reduction are as follows:—
Area of surface over which pressure was distributed..... 2.84 sq. in.
Crushing load..... 48,000 lbs.

It would appear from this that the rock is not suited to outside work but might well be used for interior construction.

Weight.—The following physical properties have been determined:—

Absorptiveness	1 : 656
Specific gravity	2.603
Weight per cubic foot	162.68 lbs.
Weight per cubic meter	2605.82 kilos.

b. Mineralogic, Microscopic and Chemical Investigation.

Under the microscope the structure of this rock is seen to be hypidiomorphic granular often with a pegmatitic arrangement of its constituent minerals.

Orthoclase is by far the most important constituent of the rock. It forms large white opaque crystals 10 to 15mm in diameter which are usually tabular parallel to the clinopinacoid (010) and are commonly twinned according to the Carlsbad law. Under the microscope they are occasionally opaque about the edges with transparent centers, but they are also often completely transparent. The cleavage-planes parallel to the base (001) and clinopinacoid (010) are very distinctly marked by the cracks across the crystal. In the opaque varieties these appear as light lines across a grayish field. An indistinct separation has also been observed in another direction and is probably parallel to some one of the orthodomes (compare page 74.) In some cases a secondary filling in of these cracks and a bordering of the whole crystal by a transparent, colorless substance has been observed. This material has a medium double refraction and a low index of refraction, but its extinction is sharp. In the cases where it fills the cracks of the crystals it is in the form of very slender wedges whose bases are in the faces of the crystals. The material presents the appearance of albite* but its character has not been definitely determined. The orthoclase is decidedly microperthitic in its structure and is very rich in gas and liquid inclusions.

* Compare Rosenbusch, Physiog. II., p. 81.

Eleolite appears in this rock in crystals which are often as much as 10mm in diameter. It is usually of a flesh-pink, oily-brown or yellow color and may easily be recognized by its greasy appearance. It occasionally appears in well defined crystals, but as a rule it is bounded by the surrounding feldspars. Under the microscope it is transparent and is easily distinguished from the semi-opaque orthoclase which surrounds it. It seems in very few cases to have undergone the decomposition which is so characteristic of it in the rocks from the Fourche Mountain region. Its double refraction is higher than that of the already described species and the sections extinguish sharply between crossed nicols. In convergent polarized light a comparatively sharp, black cross appears which, when tested with a mica plate, shows the character of the double refraction to be negative. The eleolite often contains many included basic silicates; in some cases these appear only in the eleolite and not in the other constituents of the rock. The alteration to analcite, although not nearly so common as was the case in the Fourche Mountain rock, has been observed in the rock from some localities in the Saline county region.

Sodalite has been observed in perfectly isotropic masses which are wedged in between the orthoclase crystals in the same manner as the eleolite, and they can only be distinguished from the latter by their total lack of optic activity. The cleavage cracks are indistinct and no indication of the crystal form can be obtained from them. The crystals are usually clear and show little or no indication of alteration.

Basic constituents consisting of biotite, amphibole and pyroxene are grouped together in somewhat the same way in which they appeared in the blue granite (pulaskite) of Fourche Mountain. The biotite is evidently the oldest of the three for it is always idiomorpically bounded where it comes in contact with the amphibole and pyroxene. (See p. 61).

Biotite forms small plates seldom more than 2 millimeters in diameter. They are often elongated in the direction of

one of the lateral axes so as to form long narrow plates. The optic axis angle is extremely small and the extinction is at right angles to the cleavage-planes. The pleochroism is between yellow and brown and the absorption is medium. The crystals are remarkable for the immense number of inclusions which they contain. These inclusions are in the form of neatly terminated colorless crystals which often attain a length of 0.1mm. They are prismatic in form and are truncated by an oblique plain which makes an angle of about 70° with the vertical axis. The index of refraction and the double refraction are both high. The extinction in sections approximately parallel to the clinopinacoid (010) has been observed to be about 25° and the axis of least elasticity lies in the acute angle β. This would indicate that the inclusions are allied to hornblende. Crystals of titanite are often included in the plates of biotite.

Pyroxene appears as *diopside* and forms crystals which occasionally attain a length of several millimeters and resemble very closely the forms described under gray granite (eleolite syenite). (p. 77). In this case, however, the green edges are somewhat broader and the centers are more distinctly separated from the outside zone. The angles of extinction, as measured on the inside and outside, are respectively 34° and 8°. The crystals contain a few large inclusions of other minerals, notably of biotite and apatite, and gas inclusions. Liquid inclusions have not been observed.

Amphibole occurs associated with the diopside and is generally a much more important mineral than the latter. It is the youngest among the basic silicates and in many instances it surrounds all the others. Cases occur, however, in which it is in turn surrounded by diopside. It occurs in black crystals two or three millimeters in length which, in thin sections under the microscope, are of a beautiful bluish green color. They are seldom well terminated and usually show evidence of having been corroded on the

edges by the action of the magma. They are decidedly pleochroitic according to the following scheme:—

parallel a light greenish yellow.
parallel b blue-green.
parallel c blue-green.

The absorption is b=c>a.

The amphibole appears from the foregoing facts to be allied to the *arfvedsonite group* and it probably contains a considerable amount of sodium in its composition. Its color, although the same as that of the diopside, is easily distinguished from the latter by the different shades which it assumes. While the diopside is of a grass-green or yellow-green, the amphibole has in all directions, except one, (parallel a) a bluish tinge in its color, and by revolving the section the bluish shade must appear in one position or the other. This is not the case with the diopside whose only change in color is between various shades of yellowish green. After having once established these differences, by observation on sections where the characteristic cleavage cracks are visible it is a simple matter to apply them in other cases.

The amphibole contains inclusions of the other basic silicates and notably of diopside. The latter occurs in it as small irregular plates which are characterized, as has just been described, by their yellowish green color. They give to the amphibole a spotted appearance.

Titanite appears frequently in this rock and always in its characteristic forms. Twins are rare.

Apatite and *magnetite* are both present, the latter in large crystals which often include the former.

An analysis of this rock was made by the Survey, W. A. Noyes, analyst, and gave the following results:—

Analysis of orthoclastic eleolite syenite.

SiO_2	59.62
Al_2O_3	18.67
Fe_2O_3 and FeO	5.07
CaO	1.80
MgO	0.84

K_2O	5.65
Na_2O	6.95
LiO_2	trace
H_2O (loss on ignition)	0.80
Total	99.40

It is evident from this analysis as well as from the preceding mineralogic description that this rock is almost identical with the gray granite from the Fourche Mountain region. It appears also to have much in common with the eleolite syenite, described by Brögger (Syenitpegmatitgänge, p. 33) as laurdalite, although like the similar rock from Fourche Mountain its silica is too high to make it completely identical with the Norwegian variety.

2. Plagioclastic Eleolite Syenite.

Although in its general appearance and mode of occurrence this rock is so like the preceding that it has not been possible to draw a sharp line of distinction between the two, still it seems necessary to describe the two separately, both because of the rarity of this variety of rock in the region and because, for several reasons, its description cannot be satisfactorily combined with that of the purely orthoclastic variety. As has already been stated (p. 129) the plagioclastic rock appears in precisely the same form in which the orthoclastic eleolite syenite occurs and constitutes large flat areas similar to those which were characteristic of the latter.

Structure.—Macroscopically the plagioclastic eleolite syenite has a pinkish color which is due to the eleolite crystals and it is dotted here and there with large black pyroxenes. Its structure is somewhat similar to that of the rock just described, but may be considered to be more truly granitic. It consists of a holocrystalline granular combination of eleolite, orthoclase, plagioclase and pyroxene.

The eleolite crystals are the first to catch the eye. They make up at least 25 per cent of the rock and are characterized, precisely as they were in the orthoclastic eleolite syenite, by their oily appearance and brownish pink color.

They have been observed in some cases to be as much as 5 millimeters in diameter.

The basic silicates found in the rock are usually small, but occasionally a large pyroxene crystal (5 to 10mm long) appears. The pyroxene is then easily recognized macroscopically by its black color and its prismatic angle of 93°.

The feldspathic components form small, white crystals, seldom more than 2 millimeters in length. There appears to be no recurrence of crystallization of the same mineral and therefore no truly porphyritic structure, although the difference in size of the various components occasionally causes the rock to present such an appearance.

Eleolite, when microscopically examined, is found to be identical with that of the orthoclastic eleolite syenite and its properties need no further mention. It is usually fresh, but in a few cases the formation of secondary products has been observed.

Orthoclase is much less common than the plagioclase but when present it forms the same dull, semi-opaque, tabular crystals that characterized it in the orthoclastic rock. In the plagioclastic rock the crystals are somewhat thicker, are free from inclusions, and the intergrowth with albite is less frequent.

Plagioclase occurs as fresh crystals which show a sharp extinction and are characterized by polysynthetic twinning according to the albite law. The individuals are frequently a millimeter in length (section) and about one-third that thickness. They are thin tabular parallel to $\infty P\breve{\infty}$ (010) or prismatic parallel to *a*, and are seldom, or never, perfectly terminated. Measurements made on a number of crystals which showed equal extinction angles on both sides of the composition plane gave as a mean angle 15°. This indicates that the plagioclase belongs to the *labradorite* group, but the chemical analysis of the whole rock shows so little lime that these results are open to doubt.

The albite law of twinning appears to be the only one which is of importance. The pericline law has not been

observed. Owing to the minuteness of the crystals and want of time no gravimetric separation of the feldspars was attempted. It is evident, however, that such a separation and the subsequent analyses of the material obtained would be of much value in determining the character of the plagioclase of this rock.

Pyroxene.—The only member of the pyroxene group which has been observed is *ægirite.* Although a few large crystals have been found this mineral usually appears as slender needles bounded by ∞P (110) and $\infty P\bar{\infty}$ (100). The ends of the vertical axis seldom show any truncations, but in one or two instances the base (001) and the principal negative pyramid (?) (111) have been observed. The actual linear relation of the crystallographic dimensions (not the axis ratios) which have been observed on the smaller crystals may be expressed by the following ratio :—

$$x : y : z^* = 5 : 1 : 25$$

In sections at right angles to the vertical axis the cleavage-cracks are remarkable for their sharpness and abundance.

Pleochroism is quite marked and the colors, between which the variations take place, are as follows :—

parallel a grass-green.
parallel b yellowish green.
parallel c yellowish green.

The angle of extinction in sections parallel to the symmetry-plane seldom exceeds 4°.

The index of refraction is high—higher than that of the Canada balsam—so that the sections present a slightly rough surface. The edges of the crystals are usually bounded by narrow, black bands which are produced by the total refraction of light. The double refraction is strong and the crystals exhibit high polarization colors.

These crystals seldom occur in groups but are usually found scattered singly among the other constituents. They

* These letters represent the rectangular axes whose positions are such that z lies in the same plane with a and makes this angle 15°49′ with it; y lies parallel to b and x parallel to c.

appear very frequently included in the eleolite. Many of them are of secondary origin.

Titanite is rare and *apatite* and *magnetite* have not been observed. The rock is on the whole very poor in dark colored components and phenocrystic minerals of the first generation.

Decomposition products.—In the case where the eleolite has been decomposed there appear, lying in an isotropic or weakly anisotropic groundmass, bunches of minute needles which were proved by means of a selenite plate to possess a positive double refraction. Other larger spaces when tested in the same way gave similar results. It is probable, therefore, that these needles should be referred to ranite * of Paijkull or hydronephelite † of Clarke and Diller, but want of time has prevented any experimental proof of this supposition.

A chemical analysis of this rock was made by the Survey, W. A. Noyes, analyst, with the following results:—

Analysis of plagioclastic eleolite syenite.

SiO_2	58.74
Al_2O_3	20.85
Fe_2O_3	4.15
CaO	0.36
MgO	0 22
K_2O	4.23
Na_2O	9.72
H_2O (Ignition)	1.82
Total	100.09

The analysis shows the similarity between this and the orthoclastic eleolite syenite and at the same time the excess of sodium over the potassium indicates that the plagioclastic rock is much richer in sodium feldspar, and probably also in eleolite, than the orthoclastic variety. The small amount of lime in the rock indicates that the plagioclase is albitic in its

* S. R. Paijkull, Min. Notizen. Inaug. Dissertation, Stockholm, 1875. Cited after Brögger (Syenitpegmatitgänge, p. 235). In English incorrectly spelled rauite.

† F. W. Clarke, Minerals of Litchfield, Maine, Am. Jour. Sci., Series 3, Vol. XXXI., 1886, p. 267.

composition and not labradoritic as was indicated by the extinction. The rock approaches a *theralite* in its mineralogic and chemical composition, but that it should not be called such is evident from its genetic relations and from the fact that accessory plagioclase, even in considerable quantities, is by no means uncommon in true, orthoclastic eleolite syenites.

B. Porphyritic Syenite.

In the short description that was given (p. 129) of the Saline County region the occurrence of a porphyritic variety of the syenite was mentioned. This occurs in the northwest quarter of the northwest quarter of section 23,* and it is also found at several other points, but the quantities are so insignificant as to be unworthy of special mention. The rock is of a bluish gray color and resembles very closely the blue granite (pulaskite) of the Fourche Mountain region, except that in this case the amount of augite present is much less than the amount of hornblende, and the eleolite is entirely wanting. It shows a similar but more marked trachytic porphyritic structure, produced by the large grayish orthoclase crystals lying imbedded in a fine-grained base. The only minerals which can be detected macroscopically are the orthoclase, which occurs in comparatively large crystals characterized by their perfect cleavage, and titanite, which appears in small, resinous, yellow crystals. Occasionally black prisms show the presence of some basic silicate but they are too small to allow of a macroscopic distinction between pyroxene and amphibole.

Under the microscope the porphyritic character of the rock is immediately evident. The large orthoclase crystals are usually much rounded and lie in a fine-grained, hypidiomorphic granular base made up of smaller crystals of orthoclase and the basic silicates.

Orthoclase occurs in large crystals, tabular parallel to the clinopinacoid (010), which often reaches 10 or 15 millimeters

* Nos. 277, 278 and 279 of the general table in Chap. XIII.

in its greatest dimension. The crystals are of a bluish gray color and cleave readily parallel to the base (001), showing a mother-of-pearl lustre on the cleavage-planes.

Under the microscope they are seen to be much corroded and evidently belong to the older constituents of the rock. They are often quite opaque and show sharply defined cleavage-cracks like those previously described in similar crystals (p. 132). They appear to be comparatively free from any admixture of other feldspathic material and it is only in extremely rare cases that any tendency towards a microperthitic structure has been observed.

Amphibole is by far the most important basic silicate in the rock. It occurs in prismatic crystals which are two or three times as long as they are broad. Under the microscope it is of a greenish blue color and is in every respect identical with that just described under the head of eleolite syenite (p. 134), and should probably, like that, be considered as belonging to the variety *arfvedsonite.*

The crystals of amphibole are often very much corroded and they frequently include quantities of feldspathic substance which has in some cases evidently eaten its way into the interior of the crystals and there crystallized in small individuals. In other cases this feldspathic material was probably an original inclusion of magma which afterwards assumed the form of a fine-grained orthoclase in exactly the same manner as the groundmass. In some cases the amphibole crystals are entirely made up of smaller ones which are then usually arranged in parallel positions, but small individuals are occasionally found which are not in such a position.

Biotite, when it occurs, is usually much corroded and is often surrounded with small crystals of secondary origin. In other respects its characteristics are normal.

Pyroxene has seldom been observed. When it does occur, it forms large crystals which exhibit a decided zonal structure and are surrounded with amphibole. It is of the variety diopside whose physiography has already been sufficiently described.

Titanite occurs in large quantities in all the sections, often in large idiomorphic crystals, but more commonly as small, rounded globules which possess a very high index of refraction. These are of a yellowish color and stand out distinctly from the rest of the section. One of these when tested in convergent polarized light gave the characteristic interference figure of titanite. In other respects they present very much the appearance of the perofskite grains described by Diller, Brackett, etc. (see chap. XIV).

Apatite is rare.

Magnetite is present in large crystals, but as it is always surrounded by a band of leucoxene, titanite or some other titaniferous mineral it is probable that it is itself highly titaniferous.

The *groundmass* consists of small allotriomorphic orthoclase crystals and some amphibole which are so massed and dovetailed together as to form a perfect mosaic. The orthoclase crystals are distinguished by their moderate double refraction and the fact that in convergent polarized light a single optic axis often appears. These crystals are often dotted over with minute magnetite crystals which do not seem to be titaniferous like the larger ones and in many cases appear simply as a fine dust. The small globular titanite grains already described occur very frequently in the groundmass and increase its generally dirty appearance.

In some of the sections circular spots often as much as a millimeter in diameter occur, which either contain nothing but the small orthoclase crystals just described, or else orthoclase crystals among which are scattered comparatively large plates of amphibole. These plates are often arranged in concentric circles, resembling very much the arrangement of the inclusions in leucite. The exterior form of these "groups" of orthoclase is not sharp, but in every case in which these spots have been observed they are approximately circular or else form regular polygons. It appears as though there had been a tendency to form some regular crystal but that, instead of assuming its regular internal structure, the crystal had become a mass of orthoclase which, to

some extent, preserved the external form of the uncompleted crystal. The ground for such a supposition will be found in the consideration of the pseudomorphs of orthoclase and nepheline after leucite described later. (Chapter VII. II. C. 1).

As neither eleolite nor any of its decomposition products have been observed this rock has been classed as a porphyritic syenite. It is probable, however, from its mode of occurrence that, had the conditions been right, eleolite would have been formed. It is, therefore, in reality to be considered as genetically connected with the eleolite syenite and as bearing precisely the same relation to it that the pulaskite of the Fourche Mountain region bears to the eleolite syenite.

C. Syenitic Dike Rocks.

1. Eleolite Syenite Pegmatite Dikes.

In several places in the great masses of eleolite syenite and especially in those of the southeast quarter of section 16, dikes of pegmatitic rock occur, which range from a few inches to several feet in width. These are for the most part coarse-grained and in several cases contain ores of lead and other metals in small quantities. The positions of these dikes are indicated by the orange-colored lines on maps III. and III. A. which are numbered as follows: 248, 249, 252, 258, 259, 261, 263.

Macroscopically they consist of a combination of orthoclase and a small quantity of some dark colored basic silicate, associated with the metallic sulphides when such are present. The general appearance of the rock is pegmatitic.

Microscopically the orthoclase is microperthitic in its structure and is somewhat weathered in spots. The basic silicates with few exceptions consist of *ægirite* in the form of masses of small yellowish green, acicular crystals. These are often grouped together in irregular masses as if they had been formed by the decomposition of some older minerals. In a few cases they are of larger size and show a distinct cleavage parallel

to the prism faces. The pleochroism and other optic characteristics are such as have already been described. *Amphibole* and *biotite* are of much less common occurrence than the ægirite.

Eleolite occurs in large crystals which usually occupy the interstices between the orthoclase crystals and take their form from them. In a few cases, however, they are idiomorphically bounded and then the structure becomes truly panidiomorphic granular, while in the other cases it is only hypidiomorphic granular.

There is so much difference between the various dikes that many of them must be taken up separately and their peculiarities described. It is to be understood that only those points are mentioned in which the dike in question differs from the others.

Dike No. 248 (See map III. A.) This is fine-grained and shows stout orthoclase crystals intergrown with albite (?) in microperthitic arrangement and also to a great extent surrounded by it. The albite is white and fresh and shows sharp extinction and negative double refraction. A plagioclase has been observed which is probably labradorite but it can only be considered as an accessory component. Amphibole and biotite occur in minute crystals, intimately associated with titanite and forming with it small bunches of colored crystals.

Dike No. 261. At least 80 per cent of this dike consists of flesh-colored or yellowish eleolite which is partly fresh and partly altered to long, slender decomposition products. These show a very strong double refraction which suggest the presence of cancrinite (see chap. VII. II. B. 1.) Aegirite occurs in slender needles and gives a greenish color to the rock. Orthoclase is present only in small quantities but is usually not quite fresh and therefore presents a semi-opaque appearance under the microscope.

Dike No. 263. This is coarse-grained and shows large, microperthitic orthoclase crystals often 10 to 15 millimeters in length, which are tabular parallel to the clinopinacoid (010). Between these are found large crystals of eleolite, often much decomposed, in which crystals of ægirite and occasionally of amphibole are imbedded. These ægirite crystals are of two

generations; large, idiomorphic primary crystals, and small, idiomorphic acicular crystals of a later formation.

Dike No. 252. This small dike is only a few meters long and pierces the Paleozoic rock of Cedar Park. It is peculiar in that it contains both quartz and plagioclase.

The orthoclase occurs in stout idiomorphic crystals which are often prismatic. Under the microscope it is distinctly microperthitic. The plagioclase is very scarce and occurs only in small crystals. From its extinction angle it appears to belong to the labradorite group. The quartz is in small masses included between the feldspars. It is sharp in its extinction and in a section which remained almost dark during a complete revolution of the stage showed in convergent polarized light an indistinct black cross which, when tested with a mica plate, indicated the positive double refraction of the mineral. The only basic silicate found is a bluish green amphibole which occurs in large crystals very much corroded around the edges.

In this rock both the plagioclase and quartz are accessory minerals. It is probable that the rock took up the silica necessary to form the quartz from the Paleozoic rock through which it passed.

Dike No. 249. This is of a dark yellowish brown color and is very fine grained. It is spotted with dark flecks 3 or 4mm in diameter which appear to contain small quantities of galenite.

Under the microscope the rock is seen to consist of small, lath-like feldspar crystals very irregularly arranged. Many of these show a polysynthetic twinning, while others are made up simply of two individuals in Carlsbad combination. It is probable, however, that the majority of these are orthoclase. The only basic silicate which is recognizable is amphibole; the rest, if others there be, are too much decomposed to be determined.

This rock is so completely holocrystalline and any tendency to a porpyritic structure is so entirely wanting that, notwithstanding the allotriomorphic character of its crystals and its fine grain, it has been classed among the aplitic dikes.

It appears from the foregoing that these several pegmatitic

dikes can hardly be considered as all of one kind, and yet it is probable that they were all formed from one magma and that their variations are due more to the different ways in which they cooled and to the difference in the side walls between which they are included than to any difference in the composition of the magmas from which they were formed.

2. *Porphyritic Dikes.*

The eleolite syenite is cut by numerous dikes which are porphyritic and not pegmatitic in their structure and do not resemble those just described. Two distinct types of these have been observed and they differ from each other so completely that they are described separately.

a. Ægirite Tinguáite.

Dike No. 262. This is a dark, almost black rock showing white, thick prismatic, porphyritic feldspars which often reach a diameter of 4 or 5mm. This rock grades imperceptibly into a dense, grayish rock in which the feldspars are gray and less conspicuous but still give a perfectly porphyritic structure to the dike. This dike is about 1.5 meters (5 feet) wide and has been traced for a distance of about 6 meters (20 feet).

Under the microscope the porphyritic character of the rock is very evident. The large phenocrysts of orthoclase show a thick prismatic form and are usually much rounded, although they occasionally show a very sharp contour. The sections are usually in the form of rhombs or wide rectangles which give a peculiar, spotted appearance to the rock. They seldom show any indications of an admixture of other feldspars but are comparatively homogeneous in their composition in so far as other feldspathic substance is concerned. They contain numerous minute gas-pores which are all elongated parallel to the vertical axis of the crystals and give a dusty appearance to the sections when seen with low powers under the microscope. Basic silicates of the first generation do not now exist but skeletons remain to show that they were at one time present. Thus, there

are black masses of magnetite (?) and secondary biotite so arranged as to show that a long prism of some basic silicate was once present but was destroyed by some subsequent action so that nothing but the skeleton remains.

Eleolite and sodalite have not been observed.

The groundmass is holocrystalline and consists of a mass of allotriomorphic orthoclase crystals often arranged more or less radially. These crystals vary greatly in size, the largest being about 0.2mm in length while the smallest are almost below microscopic dimensions. The larger of these small individuals are generally twinned according to the Carlsbad law. They, like the phenocrysts seldom contain other than orthoclastic material. Among the orthoclase crystals there are scattered innumerable, minute flakes of biotite which are evidentlyof a very late formation since they never show idiomorphic forms.

Magnetite and titanite occur both among the phenocrysts and in the base and present no peculiarities worthy of mention.

This ægirite tinguáite resembles in many respects the *rhomben-porphyr* of Norway (Syenitpegmatitgänge, p. 36), which has been described by many writers, but is not identical with it.

b. Eleolite Porphyry. *

This constitutes a dike (No. 267), which occurs in "Lett's mine," † an old shaft which was sunk in a search for precious metals some years ago. The dike runs approximately north and south and is about 30cm (1 foot) wide. It dips 50° S. W., and is cut at an angle of 60° by a dike of monchiquite. (See this chapter, IV. B., Dike 266.). The porphyritic dike is of a greenish color and shows lighter spots which are easily recognized as eleolite.

Under the microscope it is seen to consist of perfectly transparent, colorless eleolite or nepheline crystals 5 or 6mm in diameter, which are so rounded on the outside that no crystal form appears. They are imbedded in a fluidal mass of yellowish

* For a fuller description of this type of rock see chapter VII. II. B. 3.

† 2 S., 14 W., section 21, near center of north line of northeast quarter.

green ægirite needles which give a porphyritic appearance to the rock.

The *eleolite* is generally perfectly fresh, but it is sometimes surrounded by a narrow rim of calcite and in rare cases has been completely altered to other minerals. It contains needles of ægirite as inclusions and occasionally calcite and other decomposition products in very small quantities. Sections which remain dark in parallel polarized light give, when examined in convergent polarized light, a black cross which, when tested with a mica plate, shows the negative character of the double refraction of the mineral.

Orthoclase occurs sparingly in idiomorphic crystals, making up about 10 per cent of the rock while the eleolite constitutes at least 50 per cent of the whole.

The orthoclase is tabular parallel to the clinopinacoid (010) and is somewhat kaolinized.

Plagioclase appears usually in small, stout prisms but has been observed in larger ones which sometimes reach 0.5mm in diameter. The twinning lamellae are very distinct and the extinction measured on a few sections indicates that the plagioclase belongs to the labradorite group.

Basic silicates.—The only basic silicate which has been observed in any quantity is ægirite. It appears in large phenocrysts of a yellowish green color. These are, however, uncommon and it usually occurs in small needle-like prisms which are often very long and extremely slender. These needles have been observed in some specimens to be at least one hundred times as long as they are broad. They are perfectly straight but are occasionally cut transversely by irregular cleavage-planes. The other properties of this mineral are precisely those of the ægirite needles described elsewhere. These crystals are, however, primary and not secondary in their formation. In most of the thin sections of this rock which have been examined these small ægirite crystals are seen to form a perfect "flow structure" about the eleolite and large phenocrystic ægirite crystals and alone to constitute the greater part of the groundmass of the rock.

Apatite and *magnetite* have been observed in small quantities.

Decomposition products.—Where the eleolite is decomposed it forms needles of highly double refracting material whose composition have not been definitely determined but which evidently belong among the zeolites. Cancrinite also occurs in this rock.

It is probable that this rock is closely connected in its origin with the eleolite syenite in which it is found. Its occurrence as a dike, however, which is easily distinguishable and its very dissimilar macroscopic and microscopic appearance make its separation and special description a matter of necessity.

A very similar rock from the eleolite syenite region near Beemerville, N. J. has lately been sent to the writer by Prof. J. F. Kemp, who has in preparation a paper in which he will describe the various porphyritic forms of eleolite syenite near the "great foyaite dike" of Emerson.*

The resemblance between these two rocks is very striking and shows that eleolite porphyry dikes, like the one just described, are not confined to Arkansas but occur in other eleolite syenite regions.

D. Porphyritic Border Rock (Ægirite Tinguáite.)

The most important point at which this rock has been found in the Saline County region is on the west side of the mass of eleolite syenite in which Lett's mine is located and lies due west of the latter. This rock is of a dark bluish gray color and shows sharply defined orthoclase crystals scattered through it. It covers an area of not more than an are (¼ acre) and occurs only in loose blocks.

Under the microscope it shows a completely porphyritic structure, with large orthoclase crystals often 8 to 10mm in size, lying in a fine-grained, holocrystalline, feldspathic groundmass. The large orthoclase crystals are usually somewhat kaolinized about the outside and in the interior they contain

* On the great dike of Foyaite or Eleolite Syenite cutting the Hudson River shales in northwestern New Jersey, by Ben. K. Emerson, Am. Jour. Sci., Series 3, Vol. XXIII., 1882, p. 302.

quantities of the groundmass which has here, as well as on the outside, taken the form of small crystals of both orthoclase and plagioclase. Large biotites also occur sparingly in this rock and sometimes reach a diameter of 5mm.

The groundmass consists of a confused, but holocrystalline, mass of orthoclase, plagioclase and biotite with magnetite and titanite or leucoxene. The groundmass is stained in places by the decomposition of some of the iron ores and presents a yellowish appearance.

No eleolite or nepheline has been observed but a portion of the powdered rock, when treated with hydrochloric acid and evaporated to dryness, gave evidence by the formation of numerous small cubes of salt that sodium was present in some soluble form. It is, therefore, possible that the sodium is contained in the groundmass which is made up of such fine individuals that a nepheline crystal might easily be mistaken for orthoclase. An attempt at etching and coloring with fuchsine was not very satisfactory for, although it was evident that a little gelatinous silica was formed, it was very difficult to decide to which one of the very minute crystals it belonged. Reasoning from analogy it is fair to assume that this rock is probably one of the ægirite tinguáites which in some cases approach quite closely to the eleolite tinguáites in their appearance and characteristics. The rock is unimportant and as it cannot be found in place aids little in explaining the genetic relation of this type of rock to the eleolite syenite. Its principal interest lies in the fact that it is very similar in many respects to the tinguáites described from the Fourche Mountain region (p. 99).

IV. PETROGRAPHIC DESCRIPTION OF THE AUGITIC ROCKS.

Monchiquite dikes are found in all parts of this region cutting the syenite in all directions, as may be seen by a reference to the map and general table of igneous dikes (chap. XIII). They are usually comparatively narrow and appear as dense, black bands lying in the light colored eleolite syenites. Macroscopically most of them present the same general appearance but

differ to some extent in the size of the crystals of which they are composed. In many cases the large augite crystals are macroscopically easily detected, while in others the rock appears like a dense, black, ponderous mass, showing no phenocrysts which are visible to the naked eye. Under the microscope two types of this rock are distinguishable; they will be described separately and in the order of their importance.

A. Amphibole Monchiquite.

Under this head are described the large dikes, numbered 276 and 268 and the less important one numbered 272. These rocks consist of comparatively small phenocrysts of basic silicates imbedded in a feldspathic or glassy groundmass. The larger dikes have a general southwesterly direction and are from 5 to 10m (16 to 32 feet) wide. They consist of idiomorphic basic silicates lying in a partially amorphous groundmass. Macroscopically the rock appears almost black, but shows light colored globules, sometimes as much as 2mm in diameter, which give to it a spotted appearance. On polished surfaces these appear as small, white, nearly circular dots. When examined under the microscope the rock loses its dark, compact appearance and shows very distinctly its hypocrystalline structure. The most important crystals are the basic silicates which make up about three-quarters of the whole mass of the rock.

Augite is the most important mineral among the phenocrysts. It forms idiomorphic, thick prismatic crystals which are often a millimeter in length and of half that thickness. Under the microscope these appear a light brown, but show a slight tinge of violet which indicates the presence of titanium in their composition. They are bounded by the prisms (110), both pinacoids (100, 010), the negative pyramids (111) and the base (001), and show an inclination to form intergrowths which may be penetration twins. The usually common twins parallel to the orthopinacoid (100) are, however, in this case extremely rare. Cleavage parallel to the prism faces (110) is not as marked as in other varieties of pyroxene, but irregular cracks parallel to the clinopinacoid (010) and the base (001) are more frequently ob-

served than in the latter. The crystals show but little pleochroism and the relative intensities of the absorption of light appear to be as follows:—

$$c > b > a.$$

When polarized parallel to a a yellowish tinge is observed, while for b and c slightly violet tints prevail.

In polarized light, sections at right angles to the vertical axis are dark when the cross-hairs bisect the angles made by the cleavage-planes parallel to the prism faces. In sections parallel to the symmetry plane (010) (or nearly so) c lies in the obtuse angle β and makes with the vertical axis an angle of about 50°. Almost all the crystals show a beautiful hour-glass structure while the usually common zonal structure appears to be entirely wanting. The V-shaped, disconnected parts of the hour-glass whose bases lie in the basal planes of the crystal have a slightly smaller extinction angle than the outside portions. The large angle of extinction of the whole, when taken in connection with the light color and almost total lack of pleochroism, indicates that the augite contains more alumina than iron.

The augite contains but few inclusions. Apatite, magnetite and pyrite have been frequently noted, and in some cases biotite, which has been partly surrounded by the augite, appears. Occasionally the augite is found to be older than the olivine while in other cases the converse is true.

Amphibole in point of quantity ranks next to the augite and before the olivine and biotite. It forms reddish or yellowish brown, prismatic crystals which are sometimes double the length of the pyroxene prisms and are usually somewhat more slender.

The faces which have been observed are the prisms (110), the clinopinacoid (010), less commonly the orthopinacoid (100) and the base (001). In some cases faces were observed which were supposed to be some of the clinodomes (0m1). The cleavage cracks parallel to the prism (110) faces are very distinct and close together.

The pleochroism and absorption are very strong. The following relations exist between the axes of elasticity and the colors:—

polarized parallel a light yellowish brown.
polarized parallel b and c dark reddish brown.

The absorption is $c=b>a$.

The extinction angle between c and c is in general very small, but it has been observed as high as 6°; c lies in the acute angle β. The color, pleochroism and small angle of extinction all indicate that the amphibole belongs to that variety known as *basaltic hornblende.*

The amphibole contains but few inclusions of microscopic dimensions although apatite, magnetite and pyrite are not uncommon. Amphibole crystals frequently occur surrounding augite and are often, though not necessarily, found in parallel intergrowth with it. Olivine also occurs surrounded by this mineral.

Olivine appears in the available specimens of this rock only as *serpentine.* This decomposition product has, in almost all cases, retained the crystal form of the olivine so that there is no difficulty in determining the mineral from which it was formed. In some cases even the cleavage-cracks retain the positions that they had in the undecomposed mineral. These pseudomorphs after olivine are often 0.2 or 0.3mm in length.

Biotite occurs less frequently than the other basic silicates and, when it is present, it forms small, thin plates which are seldom more than two-tenths of a millimeter in diameter, although a few flakes have been observed which are as much as two millimeters in size. The biotite is normal in all respects and needs no particular description. The absorption of light is very great parallel to the plane of *a* and *b*. Inclusions are few in number and only those that usually occur have been observed in this mineral.

The order in which the basic silicates were formed, as indicated by their idiomorphic or allotriomorphic forms, is as follows: Apatite and iron ores, olivine, biotite, pyroxene, amphibole.

The *groundmass* consists of a transparent, colorless mass, some of which appears perfectly isotropic while the rest is

double refracting. It is probable that the double refracting minerals are plagioclase and orthoclase, for in all cases which have been tested they have been found to be biaxial. That this is the case has been shown by the extinction, which is usually inclined to what appears to be the vertical axis, and by the crystal's behavior in convergent polarized light. Under the latter conditions it is found that, where the section remains dark or nearly so, one optic axis showing a wide black band remains in the field and swings about some point as a center when the stage is revolved.

The orthoclase is tabular in form and shows a cleavage parallel to the clinopinacoid (010) which is fully as perfect as that parallel to the base (001). The character of the double refraction is negative as determined by means of a selenite plate in several sections elongated parallel to c. These crystals are naturally younger than any of the basic silicates, but where they come in contact with the uncrystallized glass they show idiomorphic forms. They include innumerable needles of apatite and also small cubes of pyrite. The plagioclase shows no very sharp twin lamellae, but is characterized by its lath-like form and its wavy extinction.

The glass occurs only in spots and consists of a perfectly isotropic, amorphous substance about which are arranged the crystals of orthoclase, plagioclase and the basic silicates. It shows no optic anomalies and appears perfectly isotropic when it has not been altered by secondary action. A thick section of a small splinter of this glass was examined and it showed no optic activity whatever. Irregular cracks occur which in some cases form angles approaching 60° and 90°, but these values are probably only accidental. A small quantity of glass obtained from this rock when heated with hydrochloric acid on an object-glass dissolved in part and showed in the dried residue gelatinous silica and small cubes of salt. In another portion, which was dissolved in nitric acid, silver nitrate produced no cloudiness thus proving that chlorine is not present. A similar test, made in a hydrochloric acid solution with barium chloride, likewise

gave negative results thus proving the absence of sulphuric acid. It is, therefore, probable that the magma which was left after the formation of the basic silicates was a strongly alkaline substance and that, in most cases, it crystallized finally in the form of orthoclase or plagioclase. These substances occupied most of the small spaces between the crystals, but when larger masses of base were formed it only crystallized about the edges and left a glass in the center. The minerals which formed during this partial crystallization probably include nepheline among them.

From the foregoing it is evident that the rock belongs to the group of augitic Paleozoic dike rocks associated with eleolite syenite and should be called, according to Rosenbusch's paper on monchiquite (l. c.), an amphibole monchiquite. (See page 109). In some respects it bears a very strong resemblance to the camptonites as, indeed, do all the monchiquites.

Before leaving the description of this type something must be said in regard to dike 272. It is not completely uniform throughout in texture and while part of it is like that just described the rest differs from it generally in being somewhat finer grained and especially in showing inclusions of eleolite syenite. These appear usually in the form of pieces of eleolite or nepheline 5 to 10mm in diameter, but in other cases masses of orthoclase, including biotite and sometimes ægirite, have been found which are several centimeters in diameter. In thin sections these fragments of eleolite syenite are seen to contain cracks into which the augitic rock has forced itself, as is proved by the fluidal structure which appears in the latter. In many specimens the dike rock presents a spongy, lava-like appearance. The included fragments show little or no evidence of having been altered by contact with the molten monchiquite and, on the other hand, the dike rock itself shows only a slight change. It seems to have become a little denser and finer grained near the edge; with the exception of olivine, none of the phenocrysts approach to within half a millimeter of the contact line.

B. Monchiquite.

This type includes rocks which are similar to those last mentioned, except that in this case the amphibole is almost com-

pletely wanting. The light colored silicates and light glassy base are either entirely absent or are present only in very small quantities. They are replaced in this rock by a dark, glassy base which fills the spaces between the bisilicates and forms an isotropic groundmass. It is unlike the light colored feldspathic groundmass decribed under the amphibole monchiquite type.

Augite and *olivine* appear in two generation and the phenocrysts often reach a diameter of several millimeters while the crystals of the younger generation are always very small. Amphibole never occurs among the phenocrysts and occasionally sinks into insignificance in the groundmass.

In order to discuss the characteristics and peculiarities of these dikes they are treated separately as was done in the case of the amphibole monchiquites.

Dike No. 253 is about 20m (66 feet) long and 45 cm (18 inches) wide. It lies in a southwesterly direction and is imbedded in the syenite to which it does not appear to adhere in the least. The augite is in this case more prominent than the olivine which is usually much altered to serpentine. The small, white, isotropic spots already mentioned are found scattered sparingly through this rock. The groundmass consists of augite and olivine, without amphibole, closely packed in the dark, glassy base.

Dike 254 is one meter (39 inches) wide and lies nearly north and south. It contains large phenocrysts of augite and olivine, often 4 or 5mm in diameter lying in a very dark, fine-grained groundmass. The olivine is colorless and shows decomposition only along its lines of cleavage which are then beautifully bordered by bands of a green material which is probably serpentine.

The groundmass contains small round spots which are usually about 0.5mm in diameter and which are filled with a perfectly isotropic substance, presumably similar to that described under amphibole monchiquite (p. 154.) These spots are much smaller and much more sharply defined than in the preceding case, and when tested with hydrochloric acid in the section they gelatinize readily with formation of numerous cubes of salt.

The presence of sulphuric acid cannot be detected microchemically. This light colored glass is frequently found included in the phenocrysts of augite.

Minute augite and hornblende needles with grains of magnetite constitute the crystals which lie imbedded in the dark, amorphous, glassy base and form the groundmass in which the phenocrysts occur.

Dike 256 forms a mass of rock about 20m (66 feet) in diameter and shows itself to be an extremely coarse-grained mixture of olivine and augite in which the former is somewhat more important than the latter. The olivine has changed entirely to calcite and other light colored decomposition products but is easily determined by its form. The groundmass is so fine and so completely decomposed that nothing can be determined in regard to its properties.

Dike 266 is 1.2m (4 feet) wide and runs in a northwest direction. It cuts the other dike (p. 147) which is found in Lett's mine at an angle of about 60°. It differs from the preceding dikes in showing some of the white, glassy base, numerous amphiboles in the groundmass and large crystals of apatite. The large crystals of pyroxene often include small olivine crystals and some of the glassy base which is occasionally altered to radially arranged zeolites. This dike forms an intermediate stage between the two types of monchiquite under consideration.

The rocks of this second type evidently belong to the true *monchiquites* which contain neither amphibole nor biotite in large quantities. They approach in some respects the *pikrites* in the same sense that the rocks of the first type resembled the *camptonites*.

V. CONTACT ROCKS.

A. Cedar Park.

Occurrence.—In the Saline County region the contact rocks play but a small part in the petrography of the igneous area. As has already been explained, the contact of the syenite with the surrounding Paleozoic rocks is everywhere covered up by sand and only in a few places, where the sedimentary rocks are

included in the igneous rocks, can such contacts be observed. In the case of the largest of these included areas, known as Cedar Park, the sandstone is for the most part entirely unaltered, but at one point on the northeast side there are a number of rocks which are either the result of a very complete metamorphism of the sedimentary rocks or else they constitute a very peculiar form of dike rock, which has been fully as much altered by the contact with the sedimentary rocks as the latter must be considered to have been if the dike is correctly associated with them.

This rock forms a band lying between an igneous dike and the sedimentary rock and on both sides the transition from it to the adjacent rock is very gradual. Two of the minerals which it contains would suggest an igneous origin for it, but the mode of occurrence of the rock appears to indicate a sedimentary origin and complete metamorphism.

Astrophyllite.—The first and more interesting of the crystals mentioned above consists of an orange- or bronze-colored mineral seldom exceeding a millimeter in its greatest dimension and especially characterized by its perfect mica-like cleavage. It was the good fortune of the writer to show a slide and a small hand specimen of the rock containing crystals of this mineral to Dr. George H. Williams of Johns Hopkins University, and to receive from him the suggestion that it was *astrophyllite* and resembled very closely the specimens from Norway described by Brögger.

In order to make sure that the resemblance to astrophyllite was not merely apparent the writer made the following tests which proved conclusively the identity of the mineral. A small flake of it was dissolved on a platinum wire in microcosmic salt and the resulting bead was heated in a reducing flame with a scrap of metallic tin. The bead assumed, after a few moments, a beautiful violet color. In order to confirm this test a little ferrous sulphate was added to the bead and it was again heated until it was transparent. While hot it appeared yellow, but on cooling it suddenly assumed a most brilliant blood-red color.

These two reactions proved beyond a doubt that titanium was present in relatively large quantities*.

Another fragment was examined spectroscopically without first dissolving it and it showed both the potassium and sodium lines distinctly. The presence of manganese was easily detected by the bluish green color obtained by smelting a small quantity of the mineral with sodic carbonate upon platinum foil.

A crystal of this mineral when examined under the weaker powers of the microscope showed the following faces: $\infty P\bar{\infty}$ (100), the perfect cleavage-plane; P (111); $P\frac{1}{2}$ (122); and $\frac{2}{3}P\bar{\infty}$ (203) (?). The angles between the macropinacoid (100) and the two sets of pyramids were roughly measured upon the microscope stage and gave the following values:—

	Measured.	Calculated (Brögger)
(100) : (111).....	45°	45° 54′
(100) : (122).....	65°	64° 9

The existence of the face $\frac{2}{3}P\bar{\infty}$ (203) could not be satisfactorily determined, although in one case a decided truncation of the angle where this face should appear was observed.

In thin sections the mineral appears in the form of idiomorphic crystals of an orange color which show a strong pleochroism. When the cleavage-planes stand at right angles to the polarization plane of the lower nicol the color is a deep orange, and when they are situated parallel to it the mineral assumes a lemon-yellow color.

The pleochroism may be expressed as follows:—

Polarized parallel a orange-red.

Polarized parallel b orange-red (or orange-yellow) †

Polarized parallel c lemon-yellow.

The absorption is as follows:—

$$a = or > b > c$$

In convergent polarized light a single axis is occasionally observed in thin sections of this mineral. In cleavage-plates the

* Astrophyllite contains theoretically, according to a formula based upon König's analysis of the mineral from El Paso Co., Colorado (Zeit. für Min. und Kryst., Vol. I., p. 423) 34.91 per cent of titanic oxide (Brögger, Syenitpegmatitgänge, p. 212).

† Brögger, loc. cit. makes this distinction between a and b, which, however, hardly appears in the saline county specimens.

optic axes are found to be too wide apart to appear in the field but it is evident that the bisectrix stands at right angles to the plane of cleavage. The extinction in parallel polarized light is parallel and perpendicular to the cleavage-planes and is sharp. The mineral is entirely free from inclusions of all kinds. It is easily distinguished from the mica group by the fact that the greatest absorption takes place when the cleavage-planes are at right angles to the plane of the nicol while in ordinary micas the reverse is the case.

Ægirite.—The other mineral of special interest in this rock occurs in long, extremely slender prisms—often 5mm in length—which seldom if ever exceed 0.08mm in diameter. Under the microscope they are seen to have perfectly sharp idiomorphic forms and seldom show any cleavage-cracks. They have a comparatively high index of refraction and show black borders along both sides, which are evidently due to a total refraction of light. From these considerations and the fact that the minute prisms seemed to have an orientated extinction it seemed possible that the mineral in question was epidote, and consequently a small crystal was detached from the rock and measured on a reflection goniometer. It gave very exactly the angles between the prism (110) and clinopinacoid (010) faces of the pyroxene group, and this in connection with the small, almost imperceptible angle of extinction shows the mineral to be *ægirite.*

The character of the almost white, semi-transparent groundmass in which these minerals are imbedded has not as yet been determined with any certainty, but as soon as this is done some light may be thrown upon the origin of the rock.

B. Inclusion in Section 21.

Petrographic description.—The rock which forms the small mass of included material described and pictured on page 128, although it appears macroscopically to be an almost unaltered shale, when examined under the microscope is seen to have undergone a very complete metamorphism. A thin section cut from a piece of rock 10cm from the direct contact with the igneous rock when examined in non-polarized light shows that it consists of a colorless, transparent base, in which are scattered small, rounded

plates of biotite which show extremely marked pleochroism and very strong absorption of light. Irregularly bounded amphibole crystals appear which present the appearance of having been very strongly resorbed, but whose irregular outline is due to an impeded crystallization and not to a secondary corrosive action.

Irregular grains and cellular masses of a light colored, highly refracting, yellowish mineral, which resembles leucoxene has been observed in many places. Its index of refraction is high, but its double refraction is low. Pyrite is also very common.

In parallel polarized light the base is seen to be made up of a complete mosaic of irregularly bounded feldspar crystals. These are fitted in together in such a way that no interstitial spaces whatever are left. The crystals are usually thick prismatic in form and show an undulatory extinction. The polarization colors are somewhat higher than those usually observed for feldspar. The character of the double refraction is negative.

If examined without a knowledge of its origin this rock would certainly be placed with the igneous and not with the metamorphic rocks.

VI. RELATIONS OF THE IGNEOUS ROCKS TO EACH OTHER AND TO THE ADJACENT SEDIMENTARY ROCKS.

In the Saline County region the relations of the igneous rocks to each other and to the sedimentary rocks are much more simple than those of the Fourche Mountain region.

The large masses of eleolite syenite were formed below a covering which, like that in the Fourche Mountain region, was sufficiently thick to allow the underlying masses to crystallize as true abyssal rocks. In a few places this overlying rock was cracked and the syenitic magma entered the break and cooled as a rock similar in structure to the blue granite (pulaskite) of Fourche Mountain.

Shortly after this the pegmatitic dikes were formed and then, after the region had cooled considerably, the porphyritic

dikes of syenitic rock were intruded into cracks in the main syenite masses.

The monchiquite dikes were probably intruded later than the syenitic dikes for at Lett's mine (the only place where the two varieties of rock are found in contact), the monchiquite dike cuts through the greenish syenitic dike.

In some cases coarse-grained veins have been observed in the syenite which have been considered as due to a segregation of the syenitic material from the wall rock and to a deposition of this in the crack in which it is found. In these cases the vein is often not completely filled to the center and the crystals of which it is composed show free ends extending into the central, open space. Small deposits of metallic ores are quite common in these veins and have led many people to spend much time and money in searching for paying "mineral" in them.

It may be stated that these segregation veins although they contain small quantities of metallic sulphides, etc., need not be looked to as sources of mineral wealth for they do not contain ore in paying quantities. This statement may also be made in regard to the monchiquite dikes which have likewise been prospected in many places. The largest of these openings and that where the most money was spent is the Lett's mine, already mentioned (pp. 147 and 157).

The syenitic rocks are older than the Tertiary deposits with which they come in contact, but in this area as in the Fourche Mountain region it is evident that a close connection exists between the igneous rocks and the deposits of bauxite in the neighborhood. In the Saline county region the bauxite is overlaid by a yellow compact sandstone of Tertiary age.

RELIEF MAP OF MAGNET COVE.

CHAPTER VI.

Geographic Description of Magnet Cove and General Distribution of the Igneous Rocks.

I. General Geographic and Topographic Features.
II. Distribution of Timber and its Relation to the Underlying Rocks.
III. Declination of the Magnetic Needle in and about Magnet Cove.
IV. Distribution of the Igneous Rocks.

I. GENERAL GEOGRAPHIC AND TOPOGRAPHIC FEATURES.

Magnet Cove is, without doubt, the most interesting of all of the regions in which igneous rocks occur in Arkansas. It has long been known to mineralogists as a locality for many rare and beautiful as well as useful minerals and there is hardly a cabinet of minerals in the world that does not contain numerous specimens from this renowned district. It is hoped that it will be possible to show in this report that that small area is of great interest not only to the mineralogist, but to the petrographer both on account of the number of varieties of rock found there and of the many instances in which the association of the rocks is such that an insight into their genetic relations may be obtained.

The name "Magnet Cove" of itself attracts attention to the locality and indicates that something out of the common order is to be expected. In the earliest records the locality was designated simply as "Cove"* or as "Cove of Wachitta."†

* Henry R. Schoolcraft, "View of the Lead Mines of Missouri, etc," p. 192. (For full title see p. 8).

† L. Bringier (E. Cornelius), in Am. Jour. Sci., Series 1, Vol. III., 1821, p. 26.

Featherstonhaugh,* however, makes mention of it in 1835 in the following words: "But what will always give celebrity to this remarkable locality, *now called Magnet Cove*, is the magnetic iron which abounds there." It is evident, therefore, that the name was given between 1819 and 1835.

The Cove proper is two miles north of the Ouachita River and twelve miles east of the city of Hot Springs. It is about a mile and a half north of the wood station, Cove Creek,† on the Hot Springs Railroad.

It is evident that the name "Cove" was suggested by the almost perfectly elliptic shape of the basin, formed by the surrounding hills. It has long been popularly supposed that this basin represents the crater of an extinct volcano and indeed this is the first suggestion which presents itself when the Cove is seen from the top of one of the adjacent ridges. The hills themselves form an almost continuous ridge about the Cove and include within their boundaries about a thousand acres of exceedingly fertile land. The exact limits of the Cove are somewhat differently defined by different people, but the most natural boundaries appear to be the following: (See Map IV.) On the north, the main sandstone ridge on whose southern slope the eleolite syenite is developed; on the east "Cove Mountain," which consists of a metamorphosed sandstone ridge flanked on both sides by igneous rocks; on the south, a continuation of the same elevation which is there known as "The Ridge," but which has the same characteristics as in the preceding case. This ridge extends west as far as Cove Creek at which point the stream has cut a deep gorge through it. On the west side of the creek the boundary of the Cove is formed by a ridge, corresponding to the one on the south in general form, but not in geologic character, for while the southern boundary consists of a metamorphosed sedimentary rock included between two masses of igneous rock, the western one is itself igneous and is bounded on both sides by the Paleozoic shales and sandstones. As this

* G. W. Featherstonhaugh, Geolog. Rept. of Exam. of Elevated Country between Missouri and Red Rivers, p. 63. (For full title see p. 10).

† This has recently been made a post-office under the name of Lecroy, but the station retains its original name.

ridge extends farther to the north it bends around toward the east and finally becomes the ridge already mentioned as forming the northern boundary of the Cove.

This northern boundary is cut off by a narrow valley from a sandstone ridge lying north of and parallel to it; this in turn is separated by a second parallel valley from the high novaculite ridges which approach it from the north.

At the northeastern corner of the Cove, Cove Creek cuts through the ridge and forms the separating line between the northern mountain and Cove Mountain. The latter rises quite abruptly two hundred feet (62 meters) above the bed of the stream (549 feet or 166 meters above sea level), but the former slopes up very gradually and the continuation of the high ridge is indicated by a small sandstone hill 70 feet (21 meters) above the creek—described later. It is at this point that opinions differ regarding what should be considered as constituting the *Cove*, for many consider that it continues up Cove Creek a mile or more and forms a long, narrow prolongation to the northeast. Some even include Cove Mountain *within* the Cove and bound it on the east by the sandstone and novaculite ridge which lies east of Chamberlain Creek. In this case the connection between the eastern and southern boundaries would be made at a point where the Hot Springs and Malvern highway crosses "The Ridge."

The interior of the Cove is drained by Cove Creek and a small feeder which comes in from the east and is known as the "The Branch." Several small streams flow into Cove Creek from the north but they are unimportant and have no names. After heavy rains the streams of this region become very high and are quite impassable since there are no bridges whatever in the neighborhood.*

The level bottom of the Cove is broken only by one elevation, a tufa hill about 50 feet (15 meters) in height. It is situated almost in the center of the Cove and was probably at one time connected with a deposit of similar material which lies west of it

* This increases the difficulty of studying the rocks of this region at certain seasons of the year, for the foot-logs which are usually placed near the fords are not sufficiently elevated to be above high water mark and are often carried away.

and on the opposite side of Cove Creek. These two tufa masses are the result of hot spring action.

Outside of the Cove there are several streams which deserve special mention as they have played an important part in the sculpture of the country. About two miles west of Magnet Cove lies Teager Creek.* This forms the extreme western boundary of the map and follows a nearly due south course. It has cut its way through the sandstone hills and ridges and forms the drainage outlet for the western slope of the western boundary of the Cove.

Stone Quarry Creek, or Stony Creek as it is also called, lies southeast of Magnet Cove and flows in general in a southwesterly direction. It follows, however, a very serpentine course, due in great measure to the different degrees of hardness of the rocks through which it has cut its way. The gorge which this stream has cut out is in many places very steep and the banks are very precipitous; at one point the bank is over 150 feet (46 meters) high and stands nearly vertical. The creek receives its name from the fact that years ago a number of millstones were quarried from the eleolite syenite which occurs near the base of the above mentioned cliff. At its headwaters this stream forms a wide, flat valley which is so filled with loose material that no rock can be found in place. Rowan's Branch, a small stream, enters this creek from the east and forms the dividing line between the syenite and a novaculite area on the southeast.

Flowing in the opposite direction, but at one point approaching quite close to Stone Quarry Creek, is Chamberlain Creek. This forms almost a letter V and flows first southwest, then west for a short distance and finally north and empties into Cove Creek just east of Cove Mountain. At the point where the creek changes its direction from southwest to north it has cut for itself a deep gorge and flows around a point of igneous rock which stands 140 feet (43 meters) nearly vertically above the stream. To the east of this point it flows between two sandstone ridges which are capped with novaculite.†

* This is spelled also Tiger, Tiga, Teaga and Panther. It is pronounced Teegur and is properly spelled as in the text.

† The novaculite ridges which appear upon the Magnet Cove map were located by Mr. L. S. Griswold of the Survey.

In considering the distribution of the igneous rock of the Cove in detail many minor points in regard to the topography and drainage will be brought out which have not seemed worthy of mention in this general description.

II. DISTRIBUTION OF TIMBER AND ITS RELATION TO THE UNDERLYING ROCK FORMATIONS.

The sudden change of character in the arboration of the hills about Magnet Cove observed in passing from the sedimentary to the igneous rocks was first commented upon by Featherstonhaugh (loc. cit., p. 62) in the following words: "At thirty-five miles from Little Rock the country is covered with ferruginous conglomerate of the old red sandstone. Wherever this latter rock is found, the pine (Pinus Australis, Mich.) prevails, as is usually the case in siliceous countries; but, about forty-eight miles from Little Rock I observed an approaching change in the timber, the pine having entirely disappeared, and being replaced by deciduous trees."

Lesquereux in the botanic and paleontologic portion of Owen's report on the geology of Arkansas* does not agree with Featherstonhaugh and the writer, for on page 342 he remarks: "From the Hot Springs to the southwest of the county toward Magnet Cove, the nature of the rocks is changed to a granitic formation, but the vegetation preserves the same character as it had on the quartz, or on the metamorphic sandstone. The banks of the creek which traverses Magnet Cove, have the Hornbeam and the Ironwood with a few Oaks and trees of the Buttonwood; where they become flat and marshy they are overgrown by the Water and Willow Oaks."

A change similar to that which occurs in Magnet Cove may also be observed in the other syenite areas, but it is not quite so evident in them because the igneous rocks are for the most part surrounded by low-lying Tertiary or Pleistocene deposits while, in the case of Magnet Cove, the high sandstone hills surround and overtop the igneous ridges. The difference in the arboration

* Second Report of a Geological Reconnoissance, etc., by D. D. Owen. Botany and Palæontology by Leo Lesquereux.

can be most plainly seen in winter after the deciduous trees have lost their leaves and when the pines form a dark green background to the masses of gray, leafless trees in the foreground.

The writer is much indebted to Mr. John F. Moore of Magnet Cove for the information embodied in the following table. Mr. Moore, having lived all his life in Magnet Cove and having had such matters brought constantly to his attention, was able to give a list not only of those trees which are now to be found in and about the Cove, but also to state the original distribution of some varieties which have now nearly or entirely disappeared.

It is evident from the table that the *Cove bottom*, which was once flat and marshy although it is now much better drained, contains such trees as are common along the river bottoms in many parts of the state.

The Igneous Border of the Cove, by which is meant the interior slopes which are covered with syenitic rock, supports mostly hard-wood growths, while the *surrounding sandstone hills* produce pine and some forms of oak which do not thrive on the syenite.

A list has been prepared which shows at a glance in which of the three divisions, mentioned above, every tree occurs. An attempt has also been made to indicate whether or not a tree is abundant in the region where it is noted by making use of two symbols to denote its presence, thus:—

C denotes *Common.*

S denotes *Scarce.*

The trees have been grouped according to their family names, and these have been arranged principally according to Gray's Manual.* The botanic names correspond with those used in the plant list published in Vol. IV. of the Report of the Geological Survey of Arkansas for 1888.

* Manual of the Botany of the Northern United States, by Asa Gray; Revised edition for 1890, New York (American Book Company), 1890.

Trees occurring in and about Magnet Cove.

No.	Family Name.	Botanic Name.	Common Name.	Cove bottom.	Igneous border of the Cove.	Surrounding sandstone hills.
1	Berberidaceæ	Berberis canadensis	Barberry	S	.....	.....
2	Anacardiaceæ	Rhus leucantha	Sumach	S	S	S
3	"	Rhus typhina	Chittamwood	S	.....	.....
4	Vitaceæ	Vitis labrusca	Grape-vine	C	S	.....
5	Celastraceæ	Euonymus atropurpureus	Waahoo (Linn)	C	.....	.....
6	Sapindaceæ	Negundo aceroides	Box-Elder	C	.....	.....
7	Leguminosæ	Robinia pseudacacia	Locust	C	.....	.....
8	Rosaceæ	Prunus serotina	Wild cherry	S	.....	.....
9	"	Cratægus coccinea	Red Haw	S	.....	.....
10	Hamamelaceæ	Hamamelis virginica	Witch Hazel	S	.....	.....
11	"	Liquidambar styraciflua	Sweet Gum	C	S	.....
12	Cornaceæ	Cornus florida	Dogwood	.....	C	.....
13	"	Cornus sericea	Swamp Dogwood	C	.....	.....
14	"	Nyssa multiflora	Black Gum	S	S	S
15	Caprifoliaceæ	Viburnum prunifolium	Black Haw	C	.....	C
16	Aquifoliaceæ	Ilex opaca	Holly	C	.....	.....
17	Ebenaceæ	Diospyros virginiana	Persimmon	S	S	S
18	Bignoniaceæ	Catalpa speciosa	Catalpa	S	.....	.....
19	Oleaceæ	Fraxinus americana	White (brash) ash	.....	S	.....
20	"	Fraxinus quadrangulata	Blue ash	C	.....	.....
21	Lauraceæ	Sassafras officinale	Sassafras	S	.....	.....
22	Urticaceæ	Ulmus fulva	Red Elm	.....	S	.....
23	"	Ulmus americana	White Elm	C	.....	.....
24	"	Celtis occidentalis	Hackberry	C	.....	.....
25	"	Morus rubra	Mulberry	C	.....	.....
26	"	Maclura aurantiaca	Bodock (Bois d'Arc)	S	.....	.....
27	Plantanaceæ	Platanus occidentalis	Sycamore	S	.....	.....
28	Juglandaceæ	Juglans nigra	Black Walnut	C	S	.....
29	"	Hicoria ovata	Black Hickory	C	.....	.....
30	"	Hicoria alba	White Hickory	.....	C	.....
31	"	Hicoria aquatica	Pig-nut	C	.....	.....
32	Cupuliferæ	Quercus alba	White Oak	S	C	.....
33	"	Quercus stellata	Post Oak	.....	.....	C

Trees occurring in and about Magnet Cove.—Continued.

No.	Family Name.	Botanic Name.	Common Name.	Cove bottom.	Igneous border of the Cove.	Surrounding sandstone hills.
34	Cupuliferæ	Quercus aquatica	Water Oak	S	.....	.....
35	"	Quercus nigra	Black Jack	.....	.....	C
36	"	Quercus rubra	Red Oak	.....	C	S
37	"	Quercus tinctoria	Black Oak	.....	C	S
38	"	Quercus phellos	Willow Oak	S	S	.....
39	"	Castanea pumila	Chinquapin	C	.....	.....
40	"	Corylus americana	Hazel-nut	S	.....	.....
41	"	Carpinus americana	Hornbeam	S	.....	.....
42	"	Ostrya virginica	Iron Wood	S	.....	.....
43	Salicaceæ	Salix nigra	Willow (common)	C	.....	.....
44	"	Salix discolor	Glaucous willow	S	.....	.....
45	"	Populus monilifera	Cotton Wood	S	.....	.....
46	Coniferæ	Pinus mitis	Yellow Pine	.....	.....	C
47	"	Juniperus virginiana	Cedar	C	S	.....

III. DECLINATION OF THE MAGNETIC NEEDLE IN AND ABOUT MAGNET COVE.

The first lines surveyed by compass in that portion of the state about Magnet Cove were run by Joseph McGuire in 1819*. He surveyed the east line of township 3 S., 17 W., but made no mention of magnetic variation and it is probable that at that distance (about 3 miles) from Magnet Cove the attraction of the lodestone bed was not perceptible.

In 1822 R. Richardson surveyed the south line of the same township for state surveyor Conway†. In order to run the line Richardson started at its western extremity and ran a random line to the east. On arriving at the eastern end of the line he found that he was 10 chains (201m) north of the southeast corner of the township. Concerning this discrep-

* See field notes in the State Land Office, Little Rock (bundle 102; book 8).

† See field notes in the State Land Office, Little Rock (bundle 104; book 145; p. 25).

ancy he makes the following note: "I find by this close a considerable convergency in the range line between Ranges 17 and 18, T. 4 S., to the adjacent meridian, caused by the attraction of a large body of loadston lying near the Ouachita river (N. E. of the corner last established on the rang line above mentioned), which i find I have fllen within the sphere of its attraction."

In regard to the east line of the next township west (3 S., 18 W.) Richardson writes (l. c., p. 31): "The range line between Ranges 17 and 18 W., T. 3 S., cannot be run with any degree of accuracy in consequence of the attraction of the loadston, as it passes very near the body and consequently I find the attraction much greater."

The east line of township 3 S., 18 W. was not surveyed until 1837 when it was run by John C. Hale (see below).

In running the line along the east side of sec. 1, 4 S., 18 W., Richardson writes (l. c., p. 18): "I find an attraction of the neadle by a body of loadstone near the Ouachita river N. E. of this place, which has caused the north part of this line to be incorrect."

In the year 1835 Featherstonhaugh wrote the following sentence* regarding the magnetic iron ore of Magnet Cove: "Some of the specimens I obtained, possess a surprising magnetic power; and such is the influence of the mass in place, that Colonel Conway, the surveyor general, informed me he had been unable to survey the country, as the needle will not traverse on approaching this locality."

On July 30, 1837, John C. Hale surveyed and sectionized township 3 S., 17 W., and ran the east line of township 3 S., 18 W.† Hale states that the township line runs through a very strongly affected region and that like many of the section lines it could only be run by back- and fore-sights.

From the personal observations of the writer and from readings taken by Mr. W. J. Hutcherson, the topographer

* Geological Report of the Elevated Country between the Missouri and Red rivers (loc cit., p. 68).

† See field notes in the State Land Office, Little Rock (bundle 128; books 384, 388, 391, and 392).

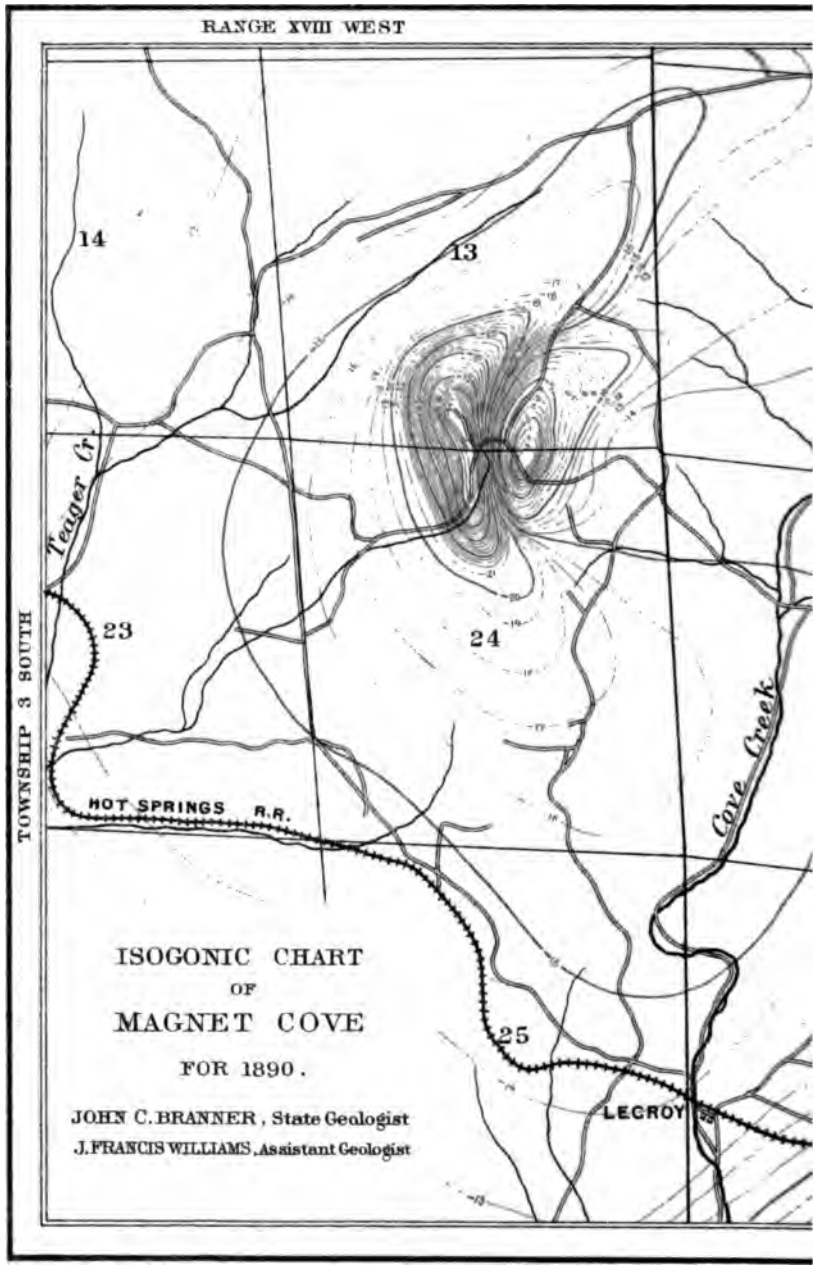
who made the contour map of Magnet Cove included in this volume (see below), it has been found that on the bed of magnetic iron ore the compass is of no use whatever. An engineer's transit, with a short needle, was set up on the top of the hill (N. E. corner of N. W. ¼ of S. W. ¼ of section 20, 3 S., 17 W.), and a stake about two hundred yards (183m) west was taken as a point at which to sight. The bearing was taken and the transit was moved ten feet (3m) further east and the bearing taken again. A difference of 13° 30′ in the bearing of the stake was observed. The transit was then placed 15 feet (4.5m) south of the original point and a difference of 15° was found to exist between the bearings of the stake taken from that point and the original station. This shows conclusively that no reliance can be placed upon compass readings on or near the lodestone region.

The normal amount of the magnetic declination as determined by the position of Magnet Cove with reference to the general isogonic lines of the state would be about 8°* east† in 1890. It will be seen, however, by an inspection of the isogonic chart (Plate 13) that, about half a mile east of the magnet ore bed the declination becomes zero and the needle points due north, while at a somewhat greater distance west of the same point the normal declination is nearly doubled. It is evident, therefore, that the effect of the magnetic force centered in this ore bed amounts to about 8° and that this extends to a distance of about a mile west and half a mile east of the disturbing area.

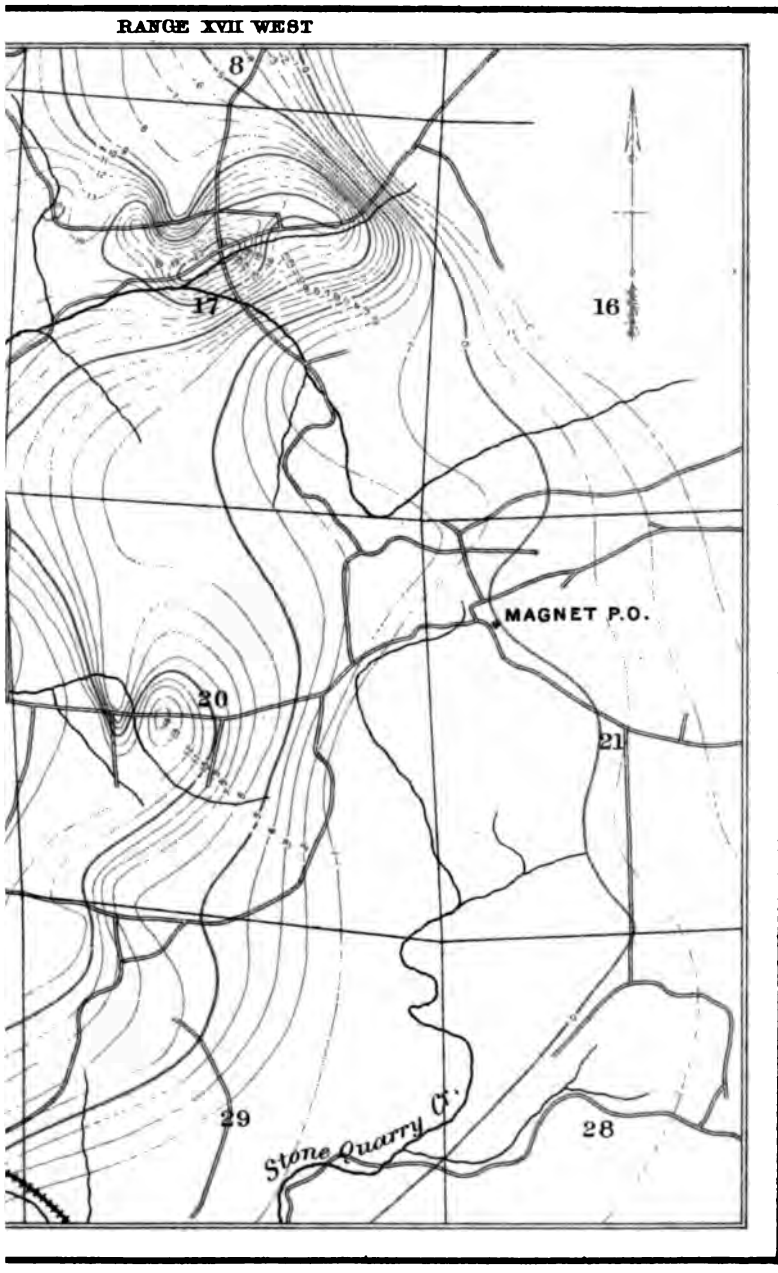
On the western side of Magnet Cove an area of still greater magnetic declination occurs. Here the variation is due to quantities of fine magnetite sand which, although apparently entirely superficial, exerts a great influence upon the needle. Its maximum effect is at a point about half a

* See Report of the Supt. of the U. S. Coast and Geodetic Survey for 1889. Washington, 1890, Appendix No. 11, 1889. "The distribution of the magnetic declination in the United States for the epoch 1890." By Charles A. Schott, p. 246. See also the observations on magnetic declination made by the Geological Survey of Arkansas and recorded in the annual report for 1891.

† Westerly declination is considered positive and is marked (+), while easterly declination is considered negative and is marked (—).



The Green Lines pass
The sign + degrees of
The Black num



...al magnetic declination
...legrees of East declination
...r U.S. land surveys.

SCALE OF METERS
0 500 1000 1500

mile west of the school-house on the hill (center of section 24, 3 S., 18 W., near the north line) and amounts to about 44°. The isogonic lines here come so near together and are so uncertain in their positions that but little reliance can be placed upon them.

There is another strongly disturbed region at the northeast corner of the area included in the chart. In this case the cause of the disturbance is a mass of lodestone quite similar in character to that in the center of the Cove. This deposit is much smaller than the "lodestone bed" and less of the ore appears on the surface. It is evident, however, that it is present in sufficient quantities to have a strong influence upon the bearing of the magnetic needle.

On the isogonic chart each green line passes through all the points, so far as it is possible to determine them from the data at hand, at which the needle is deflected a given number of degrees east or west of the meridian. These lines are so drawn that each degree from plus four to minus forty-four is represented by a line. In compiling this map ninety-three determinations of the magnetic declination were made. *

IV. DISTRIBUTION OF IGNEOUS ROCKS.

The description of the distribution of the rocks of the Cove begins with the rocks found at the point where Cove Creek cuts

* Of these 16 were determined by W. J. Hutcherson, who made the Magnet Cove map (map IV.). He established a meridian near the center of the Cove and located the principal points on the map by means of traverse lines, and occasionally determined the magnetic declination by taking the bearings of some of the trignometrically located lines. This system of surveying was unfortunately only carried as far west as the school-house on the hill, and hence it is probable that the accuracy of that portion of the map west of the school-house, embracing the most disturbed area about the Cove, suffered from the error made in considering the greatest variation to be centered at the "ore bed" in the Cove. The numerous other lines used in locating the hills, streams and other such geographic features were run by compass, and the lines were carefully "tied up" to those already trigonometrically established. Even the lines west of the school-house were tied up in this way so that the error cannot be very great and must have compensated itself. It is probable that the broken line between sections 13 and 24 which are in reality separated by a straight line is due to the fact that the line was run solely with the compass.

The 77 other determinations were made by the writer from observations taken on Polaris. These were made with a short-needle transit and were extended over a space of several hours each night until they were completed. The time of each observation was carefully noted and the approximate elongation of Polaris for that time was calculated and the correction applied. The error from these calculations falls inside of that arising from the shortness of the needle and the difficulty of reading it at night.

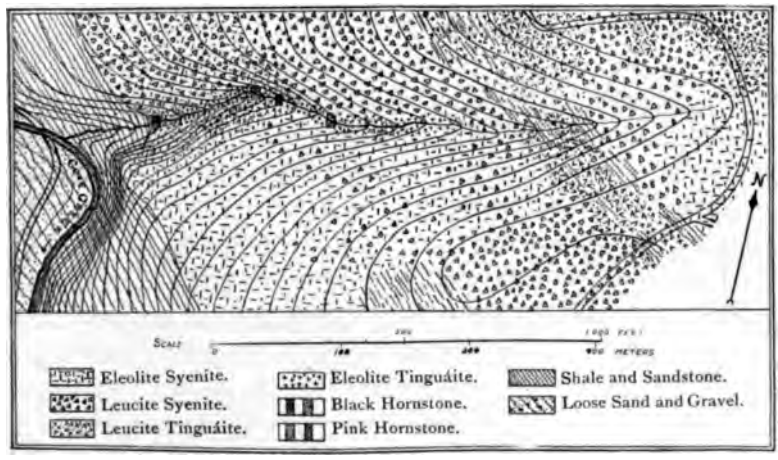
through the ridge at its southwestern corner and, following the creek to the north, mentions the occurrence of the various rocks in their order. No attempt can here be made to describe the rocks themselves but such a description will follow in the next chapter.

On going up Cove Creek from the railway bridge the stream is seen to flow over a dark shale. A short distance above the mill-pond a small gully comes down the hill on the east, and in it occurs the first outcrop of syenite. (Chapter XIII., dike 133). This is an eleolite syenite dike and forms a comparatively narrow band which extends east and west and can be traced by means of scattered boulders as far as the road which crosses the hill to the east. On the top of the small hill which lies between this gully and the next a good many boulders of leucite syenite dike rock (Chapter VII. II. C. 1) appear. This leucite material is bordered on its western side by the shales, which, on the bank of Cove Creek, form an almost vertical bluff about two hundred feet in height. In the face of this bluff several dikes of monchiquite and allied rocks appear. (Chapter XIII., dikes 127 to 132). These run in various directions, some vertical and others nearly horizontal. The fourchite and ouachitite, both of which occur in the cliff, are probably of approximately the same age, but the syenite which forms a dike cutting the fourchite is evidently the youngest of the three.

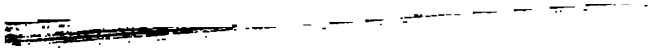
In the gully north of this bluff about 400 feet (125m) from its mouth the igneous rock appears in the form of a green and black porphyry which varies somewhat in density and structure. On going up this ravine toward the east these black and green rocks follow each other in quick succession. In some cases they may be traced up the sides of the gulch for some distance, while in others they are covered by a talus of the rock which forms the ridge above them.

The green rocks are the most typical examples of leucite tinguáites (Chapter VII. II. C. 2) to be found about the Cove; there is no one place where so many varieties of rock can be found as in this gully (See plate 14).* One of the most

*The plate represents this gully on a scale larger than that of map IV., and the distribution of the rock is shown by the various signs described in the legend. In this way the intermixtures of the various rocks can be more satisfactorily represented than by the use of different colors.



GULLY WEST OF NEASCH'S HOUSE—MAGNET COVE.



remarkable facts that has been observed in the region is the intimate connection shown between the fourchite and the tinguáite. At one point fragments or nodules of fourchite are found imbedded in tinguáite. It at first occurred to the writer that these were true inclusions brought up from below by the younger tinguáite, but on reading Rosenbusch's paper on monchiquite the possibility of their being caused by differentiations in the crystallization of the tinguáitic magma presented itself. Rosenbusch states (Ueber Monchiquite, etc., p. 465) that if mixed dikes of monchiquite material are ever found tinguáite or ægirite granite must appear.*

It may be that such a case is found in the specimen just described, but it seems more likely that it has been detached and brought up as an inclusion from below. In either case this direct association of the two rocks is very interesting.

Besides these black and green varieties of tinguáite, there is also a pink rock containing large pyrite crystals which often exceed half an inch (13mm) in diameter. It is probable that this is a bed of sedimentary rock which has been very much metamorphosed by the intrusion of the neighboring igneous rocks. East of this and further up the ravine appears another form of black leucite tinguáite in which the large pseudoleucite crystals are only indicated by grayish, octagonal and hexagonal sections and do not appear sharp and well defined. Directly above these and extending up the south bank for some distance is a bed of green leucite tinguáite and above that, still higher up the hillside quantities of leucite and eleolite syenite dike rock occur, but it is a question which of the two is in place. The indications are that the crest of the hill is occupied by the leucitic rock, while further to the west the eleolitic rock is the main rock of the hill. Between these two there appears to be a band of shale, but only loose pieces of it could be found. Returning again to the bed of the brook in the gully, the next rock east of the black tinguáite is a green

* "Würden jemals gemi-chte Gänge gefunden werden, in denen Monchiquitmaterial aufträte, so würde daneben Tinguáit oder Aegiringranit (Quartztinguáit) vorkommen müssen."

tinguáite 5 feet (15m) wide, containing extremely small pseudoleucite crystals. This, like much of the rest of this rock, shows a decided bedding like a sedimentary rock. It changes to the black variety without showing any distinct line of parting, and it is evident from both macroscopic and microscopic examinations of the two rocks that they are genetically identical. About a thousand feet (300 meters) from its mouth the shale crosses the gully in a northwest and southeast direction at two points about 100 feet (30m) apart. It dips to the southwest at an angle of about 30°. On both sides of the gulch it is covered by loose boulders of syenite and tinguáite. The latter appears as a dike between the two bands of shale and may be traced onto the hills both north and south. Still further to the east a leucite syenite dike occurs in the bed of the stream and likewise on both hills. It is probably a continuation of the mass which crosses the road in front of the house of R. F. Orr No. 1, (northeast quarter of section 30.) On the high part of the hill south of the gully beside the varieties of rock just described a small area of about 100 square feet (10 square meters), covered with loose boulders of fourchite (monchiquite) appears (Chapter XIII., dike 136).

Returning again to the gully at the point where the leucite syenite dike rock was first found on passing east from its mouth it is seen that this rock, instead of running directly up the hill to the north bears off to the west and follows the contours for about three hundred feet (91m), and then turns to the north and passes over the ridge. At two points along the line of contact between the shale and the leucite rock loose specimens of ouachitite occur (Chapter XIII., dikes 138 and 139) which fall nearly in line with the dike in the face of the cliff just south of the mouth of the gully. On following the line of contact, which is everywhere marked by the loose boulders of leucite rock, to Cove Creek, it is found to run straight down to the water's edge. Here it forms a dike (Chapter XIII., dike 140) not over 50 feet (15m) wide bounded on the north by a band of green tin-

guiáte. Just north of this the bank consists principally of sandstone which at one point lies over the igneous rock, which has been forced up under it from below, while at another point the syenitic rock lies on top of the sandstone. The igneous rock has here been forced up between the bedding planes of the sedimentary rock and where the upper layer of the latter is covered up or has been cut away the igneous rock appears to lie upon the top of it as if it had flowed out over it. At one place somewhat further up the creek (north) the leucitic rock presents the appearance of having formed a stream of molten matter showing a rapid cooling along the sides and an apparent fluidal structure in the centre. This is, however, probably the effect of exfoliation on an intruded rock and not due to a lava-like flow.

In the next gully (the one running to the north of the Neusch house) north of this hill (S. W. ¼ of sec. 19) a recurrence of various kinds of porphyritic rock similar to those in the preceding gully appears. In this case, however, the rocks are eleolitic in their character while in the preceding case they were leucitic. It appears that this gully marks the line between the leucitic and eleolitic rocks at this point. On the north side of it all the rocks are dark colored and are varieties of eleolite syenite and eleolite tinguáite (Chapter VII. II. B. 4.) while on the south side they are lighter colored and consist of leucite syenite and black and green leucite tinguáite. Metamorphosed shale also occurs in this gully near its upper or eastern end.

The eleolite syenite dike rock (fine-grained, grayish variety), which occurs on the hill north of this gully extends only to near the crest of the hill and is there replaced by a black, hornstone-like rock, whose relations to the other rocks and whose origin are more in doubt than those of any other rock about the Cove. It is called hornstone in this report because this is a name which is somewhat loose in its application. Whether further investigation proves this rock to be a metamorphosed shale or an igneous rock it is a simple

matter to insert the proper name wherever the word hornstone occurs.

In a small depression on the west side of the hill where the hornstone appears, a black porphyry or eleolite tinguáite occurs about 300 feet (91m) from Cove Creek, and covers several hundred square feet. This rock contains comparatively large, idiomorphic, white feldspars and is genetically connected with the neighboring eleolite syenite dike rocks. A dike of green leucite tinguáite 10 feet (3m) wide extends along the northern border of the depression or gully just mentioned, crosses Cove Creek and may be traced in a somewhat serpentine course for nearly 1,800 feet (546m) on the west side of the stream. The train of boulders by which its position is marked seldom exceeds fifteen feet (4.5m) in width and, although becoming here and there very indistinct, it can generally be traced with comparative ease.

Before returning to the east side of Cove Creek it is more convenient to mention the other rocks which form the high bank opposite the gully and hill just described. There is, perhaps, no part of the whole Cove region which is more confusing and uncertain than this especial hill. On the top and for a certain distance down the north and east sides the leucite syenite dike rock is exposed in large masses. Below this on the northern slope a band of green leucite tinguáite appears and still further down eleolite porphyry (Chapter VII. II. B. 3.) containing pink crystals of eleolite is found; still nearer the bottom of the hill some shale occurs which, although in loose blocks, is evidently not far from in place. Low down and near the center of the east side of the hill black and green leucite tinguáite and metamorphosed shale are exposed. The exact relative positions of these rocks cannot be definitely determined but they are probably approximately as shown on the map. Still further south, and situated in a slight depression in the side-hill, there occurs a peculiar variety of comparatively coarse-grained syenite which is everywhere much weathered and seems to have formed a miarolitic eleolite rock (Chapter VII. II. A. 3). It

is so much weathered that its microscopic characteristics cannot be determined. A similar rock appears on the northeast side of the hill just described and lies between it and a small rise which extends down to Cove Creek. This small hill lying north of the one last mentioned consists principally of hornstone which, near the creek, is probably a syenite porphyry or tinguáite. Running from the northwest corner of this hill and keeping to the southwest and south of its crest is the dike of green leucite tinguáite which has already been described. (See p. 178). This cuts through the hornstone and strengthens the supposition that the latter is for the most part a metamorphosed shale rather than an igneous rock. Opposite this hill several dikes of igneous rocks and also several beds of metamorphosed shale occur in the creek. The former are generally light colored, fine-grained dike forms of eleolite syenite while the latter are dense, compact, dark colored rocks, with a few indistinct crystals disseminated through them.

On the hill situated opposite to these on the east side of Cove Creek, and forming the point between "The Branch" and Cove Creek, more hornstone appears, but here it is interspersed with loose blocks of fourchite. Higher up the hill a light colored, banded rock occurs which appears to be a metamorphosed shale and is described later (Chapter VIII. 1.). Near the top of the hill a dark rock again appears and in many places loose pieces of fourchite are scattered over it. The latter are often amygdaloidal and show calcite filling the cavities.

Below the top of the hill on the northeast side the dark rock is soon replaced by the light colored, banded rock mentioned above. Here it seems to be more decidedly stratified, and where it has weathered it shows a distinct banded structure, but when broken the fracture seems to have little or no tendency to follow this banding. Directly below this appears the eleolite garnet syenite (Chapter VII. II. A. 2), which is characterized by its dark color, granular appearance and great weight. Below this again comes the

very coarse-grained eleolite mica syenite (Chapter VII. II. A. 1), which is very rich in eleolite and generally contains much mica. It is probably in this latter rock that the deposits of lodestone and the large masses of protovermiculite are found. On passing around the inside of the Cove and keeping along the southern ridge it is found that the same succession of rocks exists as was noticed on the hill just described. This similarity of arrangement continues to the northeast side of the Cove, but towards the last, on the southwest side of the Cove Mountain, the band of eleolite-garnet syenite becomes narrower and the hornstone comes further down the hill.

The center of the Cove consists in part, as is shown on the map, of the very coarse-grained eleolite mica syenite through which is disseminated much magnetite and lodestone. This latter mineral becomes especially abundant in one portion of the mass and the low hill on which it occurs is known as the "lodestone bed." From this hill many tons of ore have been collected and shipped or carried away, but still the supply remains equal to the demand and good specimens are always to be obtained. It is commonly believed in the Cove that this "magnet ore," as it is called, exists only on the surface and that as soon as one penetrates below the top of the ground the deposit ceases. This is in part true, for the "float-ore" is the accumulation of centuries. It has been separated out from immense quantities of syenite, which has little by little decayed and been washed away, leaving only the exceedingly heavy lodestone near the place where it was originally formed. A prospect hole was at one time opened in the lodestone bed and it was found that although pieces of the ore were obtained deep down in the decomposed syenite they were not large enough nor sufficiently abundant to warrant the opening of a mine as has been proposed. Both Featherstonhaugh (loc. cit., p. 63) and Owen (loc. cit., p. 31) were deceived by the amount of ore found on the surface and believed that it was merely the surface showing of much larger quantities below.

Much of the ore found is lodestone or natural magnet ore, while the rest of it is simply massive magnetite and is not polarized. By piling the latter into heaps with some of the polarized mineral it has been found that the non-magnetic pieces gradually become polarized and often become as strong magnets as some of the originally polarized pieces. The magnetic iron ore is usually found in smooth, round masses, entirely free from adhering pieces of other minerals, thus showing how complete the weathering has been. A few small specimens have, however, been found in which both apatite and mica (protovermiculite) are seen to be in direct association with the "magnet-ore."

It has been found by experiment that the ore does not form a valuable grade of iron when reduced in a blast furnace.

Northwest of this magnetite bed deposits of limonite and other loose sinter-like forms of hydrous oxides of iron occur. These were formed by the gradual decomposition and alteration of the magnetite. This formation will be considered again when the tufa hill in the center of the Cove is described.

All about the lodestone bed and in fact filling all this portion of the bottom of the Cove is a loose, decomposed material which consists of impure kaolin and clay in which are imbedded masses of protovermiculite often a foot (30cm) or more in diameter, schorlomite, melanite, apatite, in large single prisms and in radiate masses of small needles, eleolite in rounded masses and some brookite. Near the Baptist church along the bank and in the bed of "The Branch" there occurs a bed of coarse-grained, crystalline limestone which contains green mica usually scattered irregularly through it, but often arranged in veins. This coarsely crystalline limestone or calcite was formed by the contact of the igneous rock with a bed of common limestone, which may be part of the Lower Silurian rocks of that region. Since, however, corresponding beds are not found outside of this region, it seems more probably that the calcite was formed by the action of the igneous rocks on a calcareous hot spring deposit which was locally developed at that point.

The hill in the center of the Cove consists principally of a

siliceous and calcareous sinter, which is evidently of hot spring origin* and is subsequent to the metamorphism which altered the rock just described. On both sides of this the eleolite garnet syenite and the eleolite mica syenite appear near its base and are probably in place, while the blocks of sinter which overlie and often almost conceal them from sight have rolled down from above. Above the zone in which the eleolite rock appears the whole hill is made up of a porous sinter which in many cases contains large crystals of quartz. This hill is about 70 feet (20m) above the surrounding Cove bottom and is an oval, regularly sloping hill of comparatively slight declivity. At its eastern end it is connected with the deposit of hydrous oxide of iron already mentioned and it is probable that these two deposits are very closely connected in their origin.

In many cases the igneous rocks about the base of the hill appear to form dikes but it is probable that they are massive and that in weathering certain harder bands in them have resisted the disintegrating action better than the rest of the mass and hence remain as apparent dikes (Chap. XIII., dikes 165 to 171).

Just at the north of this hill is a spring which is remarkable on account of the continuous stream of bubbles of gas which it gives off. It was supposed that this was either carbonic acid gas or marsh gas, but on being tested, it was found to be ordinary atmospheric air. †

The spring is situated in a marshy piece of ground where no rock in place can be found but on both sides of it the eleolite garnet syenite occurs, and it is probable that either that rock or the eleolite mica syenite underlies it.

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*See Comstock's statement to this effect, Annual Report of Gelogical Survey of Arkansas for 1888, Vol. I., p. 81.

†The gas neither extinguishes a match plunged into it, nor takes fire itself. No odor of sulphur can be detected, so that the name "sulphur spring," which is often applied to it, is a misnomer. In order to make an exact determination of the escaping gas a quart bottle was filled with it and analyzed. The bottle which was to serve the purpose of collection had a funnel fixed in its neck, was filled with water, inverted in the spring and left over night. The next morning the gas was found to have expelled all the water and to have filled the bottle. The funnel was removed and the cork inserted without changing the position of the bottle and the whole was made perfectly air tight by sealing it with beeswax. The bottle and its contents were then taken to Worcester, Mass., where Prof. Leonard P. Kinnicutt of the Worcester

A hill consisting of siliceous tufa very similar to the one just described exists on the west side of Cove Creek and is so situated as to appear as if it were the continuation of the larger one in the center of the Cove. This smaller one at the west overlies a bank of the same sort of crystalline limestone as that near the Baptist church, and is in general more truly tufaceous and less filled with quartz crystals than that further to the east. It is probable that these two deposits were once connected and that Cove Creek has cut them apart. The limestone, which underlies this siliceous tufa is of a coarse crystalline variety and forms a bluff twenty or thirty feet (6 to 9m) high and might well be untilized for the manufacture of lime. A great deal of

Polytechic Institute kindly volunteered to make a complete gas analysis of it. The results of this analysis are as follows :—

Table of Gas Analysis.

TREATMENT.	Remaining volume in cc, at 747.5 mm.	Temperature Centigrade.	Volume of gas in cc. same temp. and pressure.	GAS DETERMINED.
(Original quantity).....	98.0	12.8	.....	.....
Potassic hydrate (HKO).....	97.9	12.6	0.1	Carbonic dioxide (CO_2).
Bromine (Br).....	97.9	.....	0.0	Hydrocarbons.
Gallic acid (C_6H_2 $(OH)_3$ COOH).....	76.6	12.4	21.3	Oxygen.
Cuprous chloride (Cu_2Cl_2)..	76.6	.....	0.0	Carbon monoxide (CO), etc.

After reducing the above to 760mm pressure and 0°C. temperature these figures become as follows :—

Gas analysis reduced to normal pressure and temperature.

VOLUME.	Cubic centimeters.	Per cent.	CONSTITUENTS.
Volume absorbed.....	19.03	20.67	Oxygen.
Volume unacted upon.....	73.03	79.33	Nitrogen.
Total volume taken.....	92.06	100.00	Air.

The average composition of atmospheric air is :—

Oxygen..... 20.96
Nitrogen..... 79.04

It is therefore evident that the gas which bubbles up through the spring is common atmospheric air.

it is comparatively pure, while the rest of it is filled with contact minerals, which would greatly impair its usefulness. The greatest drawback to its practical application is its coarseness, for this might cause it, when burned, to form a crumbly mass instead of close, compact stone. Its proximity to the city of Hot Springs and the ease with which it can be obtained from the bank would probably make the burning* of it on a small scale a profitable undertaking. At the south end of the knoll in which the limestone occurs is located the pegmatitic eleolite eudialyte syenite dike in which so many rare and beautiful minerals were found by Mr. William J. Kimzey†. This rock seems to have been in direct contact with the limestone and it is due to their mutual reactions that many of these contact minerals have been formed. (See chap. VIII. II. B.) Leucite rock also appears in this same knoll, but its relation to the other rocks is not quite clear. It seems as if it formed a part of the eleolite eudialyte dike which, on account of some local influence, the cause of which it is difficult to detect, crystallized in part in the form of a leucite syenite dike.

Between this knoll and the low hill lying south of it (page 179), on the west side of Cove Creek, is situated what is known as "Perofskite Hill" a very slight elevation of not more than 30 feet (10m) from which all the perofskite or dysanalyte crystals from Magnet Cove are obtained. These crystals are usually found loose on the surface but in a few cases have been found imbedded in calcite or apatite. Brookite, and the so-called hydrotitanite (a decomposed perofskite) as well as magnetite octahedrons and rosettes of rutile are also found in this same locality and all indicate that metamorphosed limestone and sandstone were once present in the hill and formed the rock in which they were produced. Loose pieces of black leucite tin-

* For suggestions on the practical construction and operation of lime kilns the reader is referred to the report on the limestones and marbles of Arkansas by T. C. Hopkins, Vol. IV. of the Annual Report of the Geological Survey of Arkansas for 1890.

† The writer has obtained from Mr. Kimzey many of the specimens described in this report from this and other localities about the Cove, and would suggest that any one wishing specimens from this region may obtain them by addressing Mr. Kimzey at Magnet P. O., Hot Spring Co., Arkansas.

guáite have been found on the hill, and near the highway hornstone and eleolite tinguáite have been observed. Due west of Perofskite Hill there rises a much steeper and more prominent hill of leucite syenite dike rock which is surrounded on the east by a band of green leucite tinguáite. On the west this hill is bounded by shale and sandstone which, as they approach the main ridge of syenite, become hornstone-like. Here and there scattered through this altered shale are dikes of fine-grained eleolite syenite. Ouachitite has also been found in loose blocks.

The main ridge forming the western boundary of the Cove consists of a fine-grained eleolite syenite dike which at certain points becomes leucitic. Thus while the bay-shaped protrusion of syenitic material extending southward into the shale is a perfect leucite syenite dike rock, it yet grades imperceptibly into the fine-grained, eleolitic rock west of it. The fine-grained syenite of this portion of the hill becomes decidedly lamprophyric and in many cases it is difficult to determine whether a specimen of this or of some dense, basaltic rock is at hand. In some cases, as for example on the west side of the ridge near the school-house on the hill, the rock becomes coarser and resembles that from the Diamond Jo quarry (see later).

In the road and generally on the eastern side of the ridge near its base, a decomposed novaculite appears which may have furnished the lime for the formation of the calcite bed already mentioned. It is a fine-grained, harsh rock, which can easily be cut with a knife and might be used for a coarse polishing powder. It is probable that this rock was present at one time in large masses on the eastern and southern sides of this ridge, although it is now completely decomposed, eroded, or covered with other materials.

In the bed of the small stream which flows into Cove Creek just north of the tufa hill on the west of Cove Creek both a metamorphosed limestone and a dark, ponderous, igneous rock occur. The igneous rock forms a 15 foot (4.5m) dike and is the most characteristic example of an amphibole monchiquite that has been found among the igneous rocks of Arkansas. It has been traced by means of its boulders for about 1,300 feet (400m) in

the direction N. 75° E. across the flats, but in the bottoms of the ditches it is found in place (see chapter XIII., dike 174). Just west of this dike and not many feet away occurs a dike of green leucite tinguáite and at several other points in that region the same rock appears. Where the road to the north crosses the hill (along the township line between sections 18 and 13) masses of fourchite and hornstone occur. About half way up the hill and just below the syenitic rock a band of green leucite tinguáite occurs as a border rock. Between this ridge and the hill lying north of it, the flat is covered with waterworn material and gives no clue to what is beneath. Along the southern boundary of the syenite both hornstone and fine-grained varieties of fourchite are found. Here and there in the ridge the leucitic rock makes its appearance but the mass of the rock consists of a garnetiferous syenite of both coarse- and fine-grained varieties*. A dark brown variety of eleolite syenite dike rock and fourchite occur in the stream bed northeast of the house marked S. W. Fordyce No. 3, and cover a considerable area. The eleolitic rock contains small masses of both eleolite syenite (Diamond Jo type) and of garnetiferous eleolite syenite (ridge type). These are of small size and appear to be local variations in the magma from which the dark colored rock was formed. Along the ridge east of this point both eleolite and leucite dike rocks occur, but the latter become more and more scarce until the eastern end of the ridge is reached. At this point there is a large boulder or loose piece of eleolite mica syenite (cove type) containing large crystals of biotite. On the south side of this ridge a good deal of weathered material occurs which consists principally of a coarse-grained sandstone, which at one time contained pyrite, and in which this mineral has now been altered to limonite. This rock has been the subject of investigation in the latest of the periodical mining fevers which has attacked Magnet Cove.

In the flat south of the end of the ridge and lying between it and Cove Creek are two outcrops of igneous rock; one a narrow dike of green leucite tinguáite, lying

* This is not the abyssal eleolite garnet syenite but a garnetiferous rock corresponding to a fine-grained rock of the Diamond Jo type of dike rock.

nearly north and south and connected across Cove Creek with a larger mass on the south side; the other a small bank of eleolite syenite dike rock lying parallel to the stream. Southeast of the end of the ridge there occurs a peculiar ring of eleolite syenite dike rock, which, starting on the west side of a small hill about 100 feet (30m) above the level of the creek bed at that point, skirts its northern side for some distance and then crosses over the ridge and takes a due southerly course to the bank of the creek. It then turns sharply to the west and follows the bank of the stream keeping about 20 feet (6m) above its bed. At the western end it becomes somewhat leucitic in its texture. The most peculiar feature of this dike formation is that nowhere does it exceed twenty feet (6m) in width and that both inside and outside of the "ring" it is bounded by sandstone.

Northeast of the house marked D. R. Rutherford, which stands on a bank of detrital material, there occur more lodestone and protovermiculite like those already described on the lodestone bed in the Cove. North of this point, loose pieces of eleolite syenite dike rock and eleolite tinguáite are scattered about. They are evidently portions of dikes which cut through the side-hill and have an approximately east and west direction. At one or two points in the beds of the streams where these dikes cross them the rock appears in place. (See chap. XIII., dikes 195, 196). At the eastern end of this dike or series of dikes, one three foot (0.9m) dike is exposed and crosses Cove Creek about 300 feet (90m) south of the house marked J. M. Henry No. 1.

Northeast of this on Cove Creek there are but very few exposures of igneous rock; several dikes of dark colored igneous rock cut the sedimentary strata in the bed of the stream; at a point about 1000 feet (300m) above the house, J. M. Henry No. 1, there occurs a dike (Chap. XIII., dike 198) of syenitic rock (fine-grained eleolite syenite dike rock) lying nearly parallel to the stream. This is bounded on both sides by shales which have been metamorphosed to

beautifully banded hornstones. The high cliff west of the northeast corner of section 17, contains a combination of various dikes (Chap. XIII., dikes 199 to 206) which is somewhat peculiar. Lying in the face of the cliff three varieties of intrusive rock appear which are distributed as follows: A dense, dark eleolite syenite dike 2 feet (0.6m) wide strikes up the cliff at an angle of about 45° to the west. Near its highest point two dikes of light-colored, syenitic rock, which make smaller angles with the horizon, intersect it. One of these is a pure eleolite syenite dike [eleolite porphyry (?)] while the other is a mixture of light and dark syenitic material. Each of these is about one foot (0.3m) wide and the upper one which contains the mixed rocks makes an angle of about 15° with the horizon, while the lower one makes an angle of about 20° and cuts the upper one near their common junction with the dark colored dike. Two other dikes of dark colored syenite are found in this cliff but they do not intersect those just described.

On the side-hill across (southeast side) Cove Creek two varieties of rock occur which differ quite decidedly from each other both in appearance and in composition. One of these is black and heavy and forms the principal rock of that side of the stream. It is well exposed in the steep banks which are from twenty to thirty feet (6 to 9m) high. This rock appears to be a form of the Cove type of eleolite syenite in which there is a great preponderance of black minerals. It is very heavy and dark and presents the appearance of a basaltic rock, but under the microscope it is seen to lie between the true eleolite syenites and the monchiquites in its mineral composition. It has been classed with the former for several reasons, among which are the following: It is older than the light colored syenite dikes which are found cutting it in dikes both large and small; its chemical composition is nearer that of the mica eleolite syenite than of the monchiquite or ouachitite of this region or of other parts of the world; its minerals are more like those of the syenite than of the monchiquite, as, for example

LIGHT COLORED SYENITE CUTTING DARK COLORED SYENITE. COVE CREEK.

the pyroxene which belongs to the diopside variety and not to the basaltic augite. Moreover, the rock is cut in several places by dikes of ouachitite, which indicates that it is older than the latter, and not of the same age as would be expected if it were grouped together with it in the monchiquite group. The fact that this dark rock is cut by sharply defined dikes of light colored syenite in every direction shows that the former must have been quite solid before the latter was formed. The fragments of the dark rock have sharp corners and angles and show that the rock was completely shattered by the intrusion of the younger rock. In many places, especially near the house marked J. M. Henry No. 8, this dark rock occurs only in very small pieces, but at other points it appears to have been broken through only in a few cracks. For an illustration of this see the view looking up Cove Creek from a point due east of J. M. Henry's house (plate 15). In this illustration the white dikes are the younger, light colored, syenitic rock which breaks through the dark rock.

On the side-hill above the point where the black rock ceases (south of the northeast corner of section 17) there appears a comparatively coarse-grained eleolite syenite, which resembles quite closely the syenite of the Diamond Jo type. This extends up the hill to the point where the novaculites occur but above them no trace of it can be found. The syenite only occurs as loose boulders and it is so weathered that no microscopic determination of it can be made. On the west side of this same hill there appears a dike of eleolite tinguáite (Chapter XIII., dike 214) which is probably about 3 feet (0.9m) wide. Its exact width and direction cannot be determined, because of the large amount of talus derived from the novaculite capping the hill, but it seems to strike straight up the western slope of the hill. On the point of the hill above the end of this dike a small deposit of rock belonging to the novaculite series occurs which, although not very important at this locality, becomes so further south and forms one of the carriers for the rare minerals of the region. This rock consists of quartz crystals which are more or

less perfectly terminated and which occasionally form the beautiful rock crystal and smoky quartz so much sought after by the mineral dealers of Hot Springs.* The crystals are, however, more commonly pressed together into a loose mass which, on being struck with a hammer, readily falls to pieces. These masses are often so loosely cemented together that mere rubbing in the hands suffices to crumble the rock to a fine sand. Magnetite grains of varying size and the renowned arkansite or brookite which has been the subject of so much discussion among mineralogists occur among these small quartz grains and are imbedded on the surface of the large crystals. These minerals will be described later under the head of metamorphic minerals (Chap. VIII. II. A.), although it is not at all certain what part the igneous rocks have played in their formation.

The side-hill south of the igneous dike mentioned above is evidently cut by similar dikes, although in no case has it been possible to determine the exact position of any of them. Their presence is, however, indicated by the loose blocks of rock found here and there and by the growth of deciduous trees which cover this part of the hill. This sudden change in arboration as indicating a change in the character of the underlying rocks on the hills surrounding the Cove cannot be too strongly emphasized.

West of this hill lies Chamberlain Creek and the space between the latter and Cove Mountain, still further to the west, is covered with both leucitic and eleolitic syenite dike rocks so intermingled that it is impossible to separate them. The land is almost all under cultivation and it is only here and there that the leucite rock forms a mass of boulders so thick that tillage is impossible. Spots where such masses of syenite occur are marked by a tangled growth of blackberry bushes and a second growth of deciduous trees and are easily recognized at a distance. There is one small patch of shale due south of the house marked J. M. Henry No. 3. This forms the top of a bank sloping steeply to the creek on the east and which on its west side shows a decom-

* The principal source of the Hot Springs crystals is, however, not this rock but the sandstone, in which the crystals appear in both large and small segregations.

posed, coarse-grained, miarolitic eleolite syenite. At this point it only appears in a few outcrops and is so much decomposed that nothing definite can be determined about it. In the stream near the foot of this bank two dikes (Chap. XIII., dikes 221 and 222) of a dark, heavy rock occur imbedded in shale and are evidently associated with the dark colored eleolite dikes already described.

The Cove Mountain forms the northern end of the horse-shoe-shaped ridge which has already been described as consisting principally of hornstone (page 177) and is itself composed of this material. It is cut in all directions by dikes of various igneous rocks and both sandstone and shale occur on it in a comparatively unaltered condition. Some of the sandstone, containing large crystals of pyrite (15 to 20mm) in a more or less decomposed state appears on the crest of the northern end of the hill. It is only a short distance away from the leucite syenite dike rock which, on the northeast side of the hill, reaches nearly to its top. Leucite tinguáite and eleolite syenite dike rock of the Diamond Jo type are also found there, but they are so covered up with leaves and mould that it is difficult to determine their exact positions. On passing along this ridge towards the south several alternations between the sedimentary and igneous rocks are observed, as is shown on the map, but the lines of demarcation between the different formations are not sufficiently sharp to allow of their exact location. Boulders of fourchite, which occur here and there scattered over the hill, are occasionally so arranged as to suggest a weathered dike.

Numerous large boulders, and a few rocks in place, which consist of eleolite porphyry (Chap. VII. II. B. 3), occur in a cultivated field northeast of Dr. J. T. Thornton's house at the southern end of the ridge. These form the most characteristic specimens of this rock which have been found and are those which were taken as the type in the petrographic description and from which the analysis was made. Their relations to the other rocks of the region are, however, entirely masked by their poor exposure and by the weathering which has taken place. It seems probable that they constitute porphyritic dikes of the eleolite syenite material which do not in appearance, structure

or chemical composition correspond with the eleolite tinguáites found elsewhere.

In their chemical composition these rocks are connected with the eleolite mica syenite, that is, the basic eleolite syenite of the cove type, while the tinguáites belong to the more acid dike rocks of the Diamond Jo type. Just north of Dr. Thornton's house is a mass of hornstone which has been used as a type for this material, the analysis of which will be found under its proper heading (Chap. VIII. I.).

The southern end of the valley between Cove Mountain and the novaculite ridge east of Magnet Post-office is filled with leucite and eleolite syenite dike rocks but, as usual, the line of separation between these two varieties cannot be sharply or distinctly drawn. At the point where Chamberlain Creek rounds the bluff near Tom Ebbs' blacksmith shop these two varieties of rock occur side by side on both banks of the stream, as is shown on the map, but even here their relations to each other are not well defined. The leucitic rock crosses the ravine west of the eleolite rock, and the two bands apparently lie parallel to each other. The eleolite syenite forms a belt not more than 15 feet (4.5m) wide between the leucite syenite and the sandstone. On the north side of the stream there is but a small quantity of this rock, and the line of contact between it and the sandstone descends the steep bank in a northwesterly direction and crosses to the west side where its occurrence has already been described (p. 190). From Ebbs' shop and extending south 20° east for a half mile (0.8km) is a band about 500 feet (152m) wide of the granular, friable quartz rock and the rock containing the large quartz crystals covered with brookite. The finest specimens of these crystals are obtained near John Watts' house.

The leucite syenite dike rock fills the valley west of this point and is well exposed just west of W. Atkins' house. The hillside south of Benj. Carr's house is entirely covered with loose pieces of Paleozoic shale intermixed with fragments of igneous rock, but the former is probably the main rock of the hill. The leucite syenite dike then bears to the east and near John Watts' house a line of boulders of a miarolitic dike rock appears. The

steep cliff above Stone Quarry Creek at this point consists principally of sedimentary rock and the leucite syenite dike rock exists only at the top; but further to the east the syenite descends to the bank of the stream and crosses to the opposite side. Leucite tinguáite appears in considerable quantities in the two streams which enter Stone Quarry Creek from opposite sides east of this point.

The igneous rock of this region is terminated on the east by Paleozoic shale and the line of contact is found to lie along the line of the north and south lane which forms the center line of section 21. Pleistocene deposits cover the shale further to the east.

Leucite syenite dike rock covers the hill lying southwest of the house marked Mrs. Winford No. 1, and, at its southeastern corner, near the lane, becomes somewhat tinguáitic, showing a tendency towards an eleolite tinguáite. Southeast of this a comparatively deep gully, made by Rowan's Branch, separates the igneous rock from the novaculite still further to the southeast. Near the house marked I. Rowan, several dikes of eleolite syenite and eleolite porphyry occur as well as a few consisting of ouachitite (?) (See chap. XIII., dikes 237–243.) These all trend in a westerly direction and near Stone Quarry Creek form a steep bluff of eleolite syenite dike rock which is separated from the leucite syenite dike rock north of it by a narrow band of sandstone. The eleolitic rock crosses the bed of the stream and forms a not inconsiderable mass on the western side, extending almost up to the leucitic rock described later. It is from this southernmost exposure of eleolite syenite dike rock (Diamond Jo type) that the millstones already mentioned (see page 9) were quarried and it is remarkable that the fragments of this rock are still comparatively fresh, notwithstanding the fact that they have been subjected to the action of the elements under most trying conditions for more than fifty years.

Just north of this point the banks of Stone Quarry Creek become very precipitous, but the steepest and highest banks are not opposite each other, so that no narrow gorges are formed. The alternation of these steep banks from one side of the stream

to the other may best be seen by an inspection of the map. The highest and steepest bank rises 140 feet (43m) above the bed of the creek and consists of a mass of leucite tinguáite, above and on the south side of which leucite syenite dike rock appears. This leucitic rock forms flat masses on the top of the bluff and by the disintegrating action of the elements has yielded a large number of loose, icositetrahedral crystals of pseudoleucite; it is probable that from this point were obtained the specimens first examined and described by Kunz (Chap. VII. II. C. 1).

Where this leucite rock comes down the hill on the southern side of the tinguáite bluff, it appears almost like a lava stream, but this resemblance is due to the weathering and exfoliation of the rock and not to any true flow, for the Stone Quarry Creek valley has been in a great part cut out since the intrusion of these rocks. The leucite rock extends nearly to the eleolite syenite dike described above and is only separated from it by a narrow band of sedimentary rock.

At several points on the comparatively flat top of this hill there are found spots covered with loose boulders of the green leucite tinguáite and at other points boulders of monchiquite may be observed. The location and approximate extent of these deposits is indicated on the map, but very little reliance can be placed upon the accuracy of the details in this instance, since the position of. the rocks could only be determined from loose material. The southern boundary of the leucite syenite dike rock is approximately a straight line which falls in line with the syenite dikes near Rowan's house, and which extends towards the west, with only one break, to beyond the Diamond Jo quarry described later. On a small spur on the southwestern side of this hill a small area of eleolite syenite of the Diamond Jo type appears, and between that and the leucite rock, from which it is separated by shale, there are a few boulders of ouachitite.

The specimen of leucite syenite dike rock represented in plate 17 (See Chap. VII. II. C. 1) was found on the mass of leucite rock which comes down to the creek from the east, nearly opposite to the high bluff just described, and well illustrates the frequency with which the pseudoleucite crystals

occur. A little farther up the stream, but still on the east bank, the altered sedimentary rock appears and forms a point which extends toward the west. The leucite syenite dike rock then appears again at the water's edge and forms a considerable mass on both sides of the stream. The sedimentary rock forming the bank further up the stream cuts off this rock and is itself finally supplanted for a distance by a dark, porphyritic eleolite rock, but it appears again at the point where the valley bends to the east. Opposite this point is the bank described (page 193) where the leucite dike rock is on top of the bank while the shale forms its lower slopes. West of this the whole hill as far as Versar's Branch is made up of shale, but the point which extends from the main ridge toward the south and forms the dividing line between Versar's Branch and Stone Quarry Creek, is made up of an extremely confused mass of leucite syenite dike rock, leucite tinguáite, eleolite syenite dike rock, both coarse- and fine-grained, and of metamorphosed sedimentary rock. The approximate positions of these various rocks are indicated on the map, but as most of the country is thickly wooded and the character of the rock could only be determined from the loose pieces found, the lines of separation are, therefore, not very accurate. The small, narrow projection on the east side consists of an eleolite syenite dike (Diamond Jo type) and bears a strong resemblance to a lava flow, but is the result of unequal weathering and erosion. On the west side of Versar's Branch the land is mostly under cultivation as far as the road along the ridge, while the rest is covered with woods in which little or no rock can be found in place. The lower part of the hill and the stream bottom are probably made up of shale which on the higher parts of the hill contains green and black leucite tinguáite as well as hornstone and a fine-grained, porphyritic syenite. Boulders of fourchite and monchiquite have been found here and there, as for example, on the highest point of the hill, but they are not at all common. The top of the ridge consists principally of hornstone which extends down to the eleolite garnet syenite on the inside of the Cove basin. The ridge is occasionally crossed by the black eleolite tinguáite which can often be traced by means of

boulders for some distance in a general west-northwest direction. The positions of these dikes are indicated on the map, and some of them are numbered and described in the general table. (Chap. XIII.).

Southwest of the house marked J. N. Johnson No. 1, there occurs a green leucite rock which, when broken, does not present the glassy appearance so characteristic of the dike form of leucite tinguáite. It contains large crystals of pseudoleucite some of which are more than three inches (76mm) in diameter. They usually weather white and appear as large, white, polygonal (usually hexagonal) spots on the dark, bluish green stone. The weathering of the mineral and the matrix seem to take place at equal rates, so that the surface of the rock always remains smooth. It is impossible to discover the exact extent of this rock or of the black eleolite porphyry or tinguáite with which it is closely connected both in position and origin. It is, however, not improbable that this green leucite tinguáite marks the northwestern limit of the leucitic rock forming the high bluff already described (page 194), east of it and that the eleolite porphyry is only a phase of the same rock. Somewhat further south, but still on the same hill, there appear boulders from one of the eleolite tinguáite dikes mentioned above, (page 196) as well as loose pieces of monchiquite rock and fragments of shale.

In front of J. N. Johnson's house and all along the "ridge road" boulders of tinguáite and of fourchite occur but it is only in rare cases that they can be located with any accuracy.

The ridge forming the southern boundary of the Cove consists principally of hornstone which is separated from the eleolite garnet syenite by the white, spotted rock mentioned above and occurring south of J. F. Moore's house (page 179). The hornstone forms the top of the hill and is frequently intersected by dikes of eleolite tinguáite and by small masses of rock belonging to the monchiquite group. In many places it is absolutely impossible to decide which of the boulders belongs to the prevailing rock of the locality. Near J. D. York's house and on the lane running thence toward the south there is much eleolite tinguáite and monchiquite exposed; it seems

more probable that these rocks are in the form of narrow dikes in the hornstone than that they constitute any considerable independent masses. The line of junction between the hornstone and the leucite syenite dike rock keeps near the crest of the hill and is at this point marked by the occurrence of tinguáite. The leucite syenite dike rock forms the greater part of the mass of the igneous rock, but it is found in many cases to change almost imperceptibly into eleolitic rock of either the Diamond Jo or the garnetiferous eleolite syenite (ridge) type. About half way down the southern slope of the ridge several parallel bands of sedimentary rock appear. These are not very wide but they seem to follow a nearly east and west course and, if their appearance in successive gulleys and roads may be taken as an indication, they seem to be continuous. The whole side-hill is covered with loose boulders of syenite and scattered here and there among them loose pieces of sedimentary rock occur, indicating that the latter is probably more plentiful among the igneous rocks than might be supposed. The presence of these loose pieces of rock is indicated on the map by crosses and bands of the sedimentary color over the igneous background.

Some clue to the conditions under which the rocks of this ridge have been formed may be obtained from the occurrence of a dike* of eleolite syenite lying about 200 feet (61m) south of the main mass of igneous rock. This dike has been traced in an east and west direction for over 1500 feet (457m) and seems to be

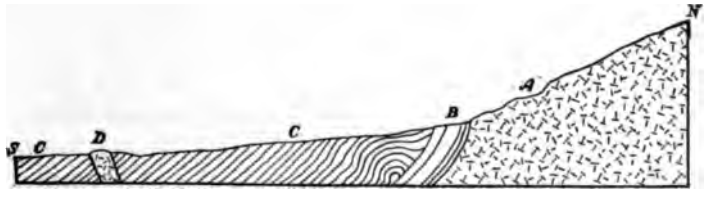


Figure 9. *Section south of Diamond Jo Quarry Magnet Cove.* Scale—1 : 1600 (100 feet=1¼ inches).

A. Eleolite syenite dike rock (Diamond Jo type).
B. Metamorphosed sedimentary rock.
C. Paleozoic rock.
D. Eleolite syenite dike.

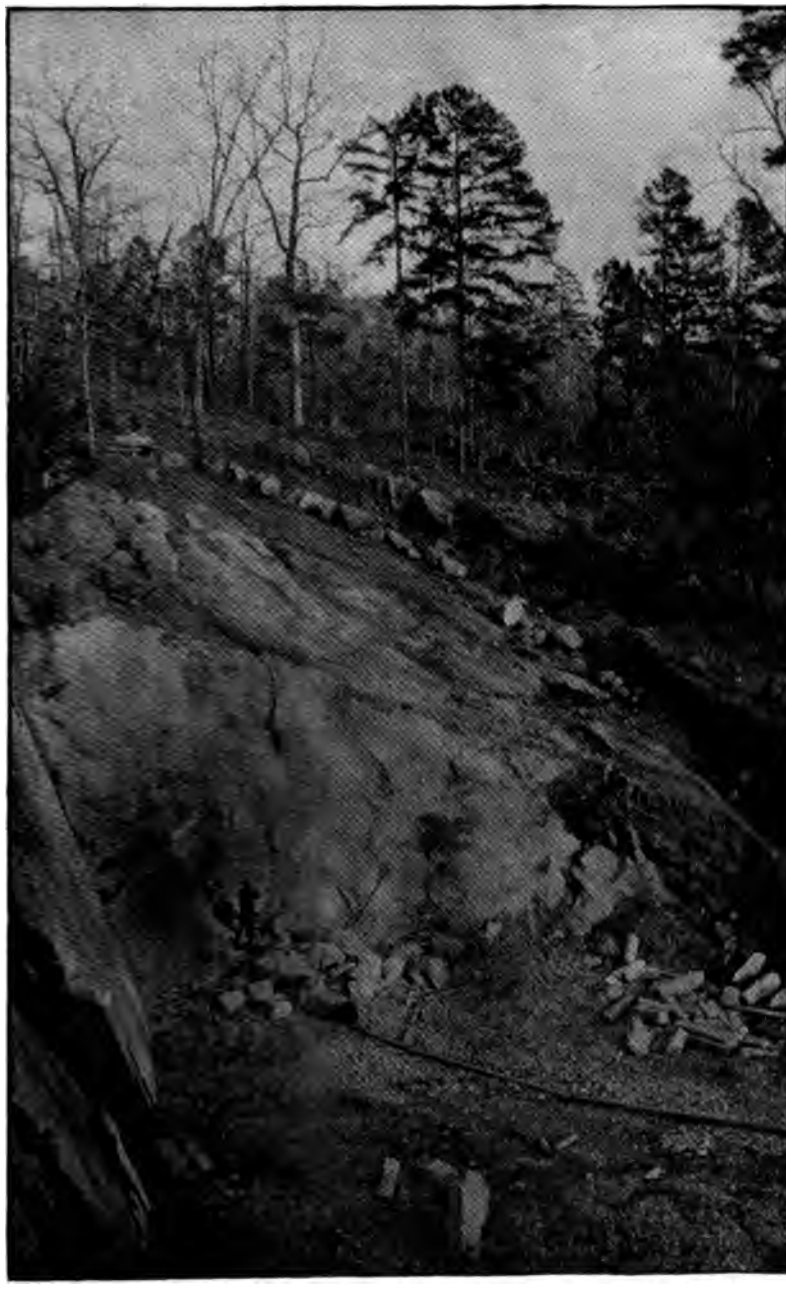
* Dike 233 of table in Chap. XIII and map IV.

perfectly uniform in width throughout its entire length. It comes up through the shale in a direction almost parallel to the contact between the shale and the south side of the main mass of rock of the Diamond Jo quarry (Fig. 9). A band of shale separates the two exposures and shows that each of the masses of igneous rock was intruded into the sedimentary rock across the stratification, but in the direction of its strike. The same thing has been repeated several times further up the hill and differs from this case only in the fact that there the masses of intrusive rock are larger and the sedimentary beds narrower. In this way the numerous bands of shale and the fragments of sedimentary rock found among the igneous rocks are accounted for. In most cases where the sedimentary rock is found in place in the stream beds a band of tinguáite occurs on either one, or both sides of it. This shows very conclusively the border character of the tinguáite and the intrusive character of the syenitic dikes.

The southern edge of the main igneous mass consists principally of an eleolite syenite dike rock which in some places passes into an eleolite tinguáite. The eleolite syenite dike rock has been opened at the point marked "Diamond Jo Quarry"* and has proved itself to be a superior building stone both in appearance and durability. It is, on the southern side of the opening, in direct contact with the sedimentary rock which it has metamorphosed for a distance of several feet from the line (See chap. VIII. I.). The contact is shown in plate 18 (Chap. VIII. I.) and a general view of the quarry is obtained from plate 16. In the latter picture the peculiar weathering of the eleolite syenite into boulders which lie buried only a short distance below the surface is shown by the line of such boulders on top of the main body of the rock. The rock of the quarry which, by the way, like all the other syenites of Arkansas is called granite, shows numerous variations in structure and size of grain. It takes a beautiful polish and is a most ornamental and desirable stone for interior work†. In regard to its mineral constitution

* This quarry was owned by the late Mr. Jo Reynolds of Chicago, Ill. and was purchased by him in order to supply the Hot Springs Railroad, of which he was the principal owner, with a good material for bridge piers, arches and buildings.

† See the frontispiece (plate 1) in which a polished surface of this stone is reproduced.



DIAMOND JO QUARRY. SHOWING WEATHERED BOULDERS AND CONTACT.

and structure the reader is referred to the petrographical description of the eleolite syenite dike rock (Diamond Jo type) (Chap. VII. II. B. 1).

At a point just west of the quarry a large rock was found which shows very well the intimate relations existing between the eleolite rock of the quarry and the leucite rock just north of it. This mass of rock consists principally of leucite syenite dike rock and between the masses of that material the eleolite syenite dike rock forms a cementing mass showing a sort of fluidal structure in some places and at other points forms a coarse crystalline mass, without any indication of a magmatic flow and much resembles the rock from the quarry. It is evident from the indistinct lines of separation and the mutual interpenetration of the two rocks that they were formed from the same magma by different conditions of crystallization and not by the subsequent eruption of the eleolite rock and consequent resmelting of a previously formed leucite rock. The accompanying sketch of this rock (Fig. 10) was drawn from a large photograph which was not suitable for direct reproduction.

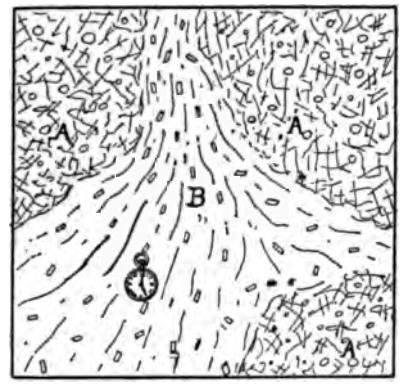


Fig. 10. *Eleolite and leucite dike rock near Diamond Jo quarry.* Scale—1 : 10.
A. Leucite syenite dike rock. *B.* Eleolite syenite dike rock.

On the road from Cove Creek station to the top of the ridge near the house marked R. F. Orr No. 1, the recurrence of the various bands of igneous and sedimentary rock may be studied in detail to advantage. A narrow band of eleolitic rock crosses the road just south of the house marked J. H. Lecroy

No. 1, (Chap. XIII., dike 134) and is, possibly, the western prolongation of the dike which lies south of the Diamond Jo quarry, although it does not resemble it in structure. This dike is much more tinguáitic or lamprophyric in its character than the coarse-grained syenitic dike. There are two dikes of this character not far apart but north of them and to the point where the main mass of syenite is reached an arenaceous shale constitutes the hillside. The main mass of igneous rock begins with a leucite syenite dike rock instead of with an eleolite rock, as might be anticipated from what has been observed at the Diamond Jo quarry, and the road is then crossed by two bands of sedimentary rock as already mentioned (page 174). These are separated by a black, dense eleolite syenite and above them an eleolite syenite occurs. Next to this is a band or mass of monchiquite (fourchite), then more leucite syenite dike rock appears and a second band of fourchite crosses the road. The leucite syenite dike containing the large crystals which has been previously mentioned as appearing in front of R. F. Orr's house, No. 1, crosses the road next above these and on both sides of it are found narrow bands of green leucite tinguáite. Beyond this the road descends into a slight depression, where is situated a train of loose boulders of fourchite; beyond this the road forks, one branch of it running along the ridge to the east and the other branch crossing over into the Cove. The latter passes first over hornstone in which there are evidently numerous dikes of both eleolite tinguáite and members of the fourchite group as is shown by the loose boulders of these rocks scattered everywhere among the fragments of hornstone. Near the junction of the road running from J. Neusch's house toward the north there is considerable fourchite, but it is probable that it does not form as large a mass as its boulders would suggest or as is indicated upon the map. Just before coming to the band of light colored, speckled, metamorphosed rock, a dike of the eleolite tinguáite with the large feldspars, similar to those already mentioned (p. 178), occurs. Beyond this the road crosses the light colored, speckled and banded rock and then passes to the eleolite garnet syenite (ridge type) as already described.

The minute description of the sequence of the rocks observed in this road has been given as a specimen of the confusing way in which the rocks succeed one another and in order to give some idea of the difficulty of tracing out the various kinds of rock where they are not exposed in a road but are concealed by soil and vegetation.

On the continuation of the ridge of the hill to the northwest of the area covered by fourchite (center line between S. E. and S. W. quarters of section 19) several dikes or masses of black eleolite tinguáite appear which are very well characterized and resemble that found lower down on the west side of the same hill and already described (page 178).

With this description the "magic circle" about Magnet Cove is completed and while only in one or two cases has a detailed description of the occurrence of the rock been entered into, it is hoped sufficient has been said to make intelligible the petrographic description of the rocks themselves which follows in the next chapter.

In describing those dike rocks shown on the Magnet Cove map as lying outside of the Cove ring it has been thought best to arrange them in the form of a table and not to attempt any detailed description of them in this place. The numbers in the table refer to the numbers on the map and are used for the most part only for those dikes which can be represented solely by lines and whose character cannot be determined from the coloring of the map. (See Chapter XIII.).

Some of the tinguáite dikes lying outside of the Cove need, however, a few words relative to their occurrence in general and as this matter cannot be given in the table it is added here. In some cases these dikes are not noted in the table.

The leucite tinguáite dike cutting across Cove Creek about three hundred feet (91m) below the railway bridge extends to the west across the south end of the small hill shown on the map. About 300 feet (91m) further west it is lost in the Pleistocene gravel.

Another dike (Chap. XIII., dike 48) of similar material begins one-third of a mile (536m) further south and makes nearly

a quarter of a circle ending at the foot of a steep ridge covered with novaculite debris and not far from the section line between sections 25 and 26. (Dike not shown on the Magnet Cove map. See map I.)

Again west of Teager Creek about a quarter of a mile (400m) west of the curve at the point where the Hot Springs railroad comes nearest to the east and west line of sections 23 and 26 a similar dike (Chap. XIII., dike 47) appears and extends to the north until it intersects the Hot Springs railroad at a point about 300 feet (91m) west of the bridge over Teager Creek.

The rocks of these dikes are of a greenish color, but some of them show a denser and more compact structure than the others. In that portion of the last mentioned dike which lies nearest to the railway many large, flat, tabular feldspar crystals occur which in their crystal form resemble sanidine very closely. They are so weathered that no investigation of their lustre, optic properties, or general physical characteristics can be made.

CHAPTER VII.

Mineralogic, Petrographic and Chemical Characteristics of the Igneous Rock from Magnet Cove.

I. Special Petrographic Literature.
II. Petrographic Description of Feldspathic Rocks.
  A. Eleolite Syenite.
    1. Eleolite mica syenite (Cove type).
    2. Eleolite garnet syenite (Ridge type).
    3. Miarolite eleolite syenite.
  B. Eleolitic Dike Rocks.
    1. Eleolite syenite dike rocks (Diamond Jo type).
    2. Eleolite eudialyte syenite (pegmatite).
    3. Eleolite Porphyry.
    4. Eleolite Tinguáite.
  C. Leucitic Dike Rocks.
    1. Leucite Syenite dike rock.
    2. Leucite Tinguáite.
      a. Border type.
      b. Dike type.
III. Petrographic Description of Augitic Rocks.
  A. Fourchite Group.
  B. Monchiquite Group.

I. SPECIAL PETROGRAPHIC LITERATURE.

Magnet Cove has been so often mentioned in connection with the minerals that occur there that it is remarkable that more attention has not been paid to the petrography of the rocks in which and through whose agency these minerals have been formed. As it is, the few articles reviewed in Chapter II. are the more important of those which have been published; they are the only ones which have any direct bearing on this subject.

Some of these papers deserve more minute attention than they there received and consequently this section has been devoted to their discussion.

Featherstonhaugh.—From Featherstonhaugh's report* it appears that he grasped the relation of the igneous to the sedimentary rocks in so far as their relative ages are concerned, for he says: "From a careful examination of the different portions of this most interesting cove, I came to the conclusion that the whole structure of this elevation, as far as its exterior as well as its interior slopes were concerned, was an old greenstone belonging to the intrusive rocks, and occupying, for a limited space, a place amidst the old red sandstone. * * It is impossible to look at this quasi-circular brim and the cove below, and take into consideration, at the same time, all the minerals and metals found there, without being impressed with the opinion that it is the result of a very remote volcanic action, and is, perhaps, one of those extremely ancient craters that may have preceded those of which basalt and lava are the products." Thus he distinctly speaks of the rock as being of intrusive origin, but seems to have been impressed with the idea that the cove is an extinct crater. In speaking of the rocks which he found in the interior of the cove he says (p. 62): "In various parts of the bottom, I found large masses of decomposing felspar, studded with black tourmalines, † some of which were in long prisms, whilst others formed a stellated figure of beautifully delicate acicular rays. Some of the feldspathic rocks were filled with amorphous masses of white sulphuret of iron, believed by many persons to be silver. In other parts of the cove I found masses of coarse grained syenite consisting of red felspar, ‡ hornblende, || mica, and some quartz." § He then describes the magnetic iron ore and states it as his opinion that "masses of the metal of prodigious extent" exist below the surface.

* Geological Report of the Elevated Country bet. the Missouri and Red Rivers, p. 63.

† Evidently the large ægirite crystals so well known from this locality.

‡ The pink eleolite of the eleolite syenite.

|| Ægirite imbedded in the rock.

§ Yellow eleolite in the eleolite syenite.

Powell.—In a foot note in his work on Fourche Cove * W. B. Powell writes as follows: "From specimens I have seen from the Saline, Magnet Cove and Little Missouri (and other similar locations may exist unknown to the scientific) I am justified in concluding that this formation (granite and its immediate associates) with slight variations, continues southwest from the Fourche Cove a hundred or so miles."

Shepard.—The mention made by C. U. Shepard of eleolite † and eudialyte ‡ have already been noted under the general literature and are important as being the first recorded identification of the mineral eleolite and therefore the first suggestion of the existence of an eleolite syenite in this region.

In a foot note to the earlier of these two articles Shepard describes from Magnet Cove the following rock which he received from Rev. E. R. Beadle of New Orleans:—

"From Magnet Cove, (Sec. 19, 3 S., 17 W.). A ryakolite-porphyry with a dark green basis. The rock contains little specks of a rich, azure blue mineral, which I am unable at present to determine."

Owen.—In his report upon the Geology of Arkansas ‖ D. D. Owen describes Magnet Cove in detail. He gives the following list of minerals found there :—

"Black garnets, crystallized.	Iron pyrites, crystallized and amorphous.
Green, yellow and black mica, crystallized.	Strontianite? crystallized.
Schlorlamite, crystallized.	Arkansite, crystallized.
Quartz, crystallized.	Elæolite, crystallized.
Lydianstone.	Actinolite, crystallized.
Agate.	Epidote, crystallized.
Pyroxene, crystallized.	Arragonite, crystallized.
Hornblende, crystallized.	Talc.

Magnetic iron ore. and, no doubt, many other minerals exist not yet enumerated."

Under the head of "most prevalent rocks" he mentions :—

Novaculite.	Milky quartz.	Hornblende rock.
Quartzite.	Chert.	" porphyry.

* A Geological Report upon the Fourche Cove, etc., p. 6.

† Am. Jour. Sci., Series 2, Vol. II., 1846, p. 249.

‡ Am. Jour. Sci., Series 2, Vol. XXXVII., 1864, p. 405.

‖ Second Report of a Geological Reconnoissance of Arkansas, etc., p. 30-31.

Sienite.	Burrstone.	Hornblende slate.
Granite.	Kisselschiefer.	Schorlamite rock.

He mentions the magnetic iron ore and the extremely pure form of titanic oxide which is known as brookite or arkansite.

Again, on pages 104 and 105 Owen refers to Magnet Cove and describes the magnetic iron ore more in detail and gives a chemical analysis of it. (See chap. VII. II. A. 1). In regard to its occurrence he says: "The lapping of the arable land on the margin of the magnetic iron ore conceals its relation to the adjacent rocks; but from the minerals ploughed up in the fields on the south and southeast, the magnetic iron ore seems to be surrounded, in part at least, with mica slates. Along with the large flakes of this mineral, brought to the surface by the plough, are beautiful crystals of augite, and black garnets. Adjoining the flucan of mica is a schorlamite granite." * * *

"A short distance on the west side of Cove Creek, on the west part of section 19, a heavy vein of calc spar forms a low ridge, twenty or twenty-five feet in height. This calc spar can be traced 400 yards; and adjoining it, especially on the west, a great variety of minerals can be found, amongst which the ores of Titanium are the most interesting. Still further to the west and south, different varieties of granitic and augitic rocks prevail, succeeded on the northwest by the so-called 'Mountain rock' passing into quartzite and novaculite."

Foster.—In 1869 J. W. Foster published a book on the physical geography of the Mississippi Valley,* in which he mentions the rock of Magnet Cove in a general way. † On page 255 he states under the heading of "The Lake Superior System" the following theory: "At that time, the Alleghanies and Rocky Mountains had not assumed their form and direction, and the only objects which rose above the barren waste of waters to break the monotony of the scene, were a few isolated islands,

* The Mississippi Valley: its Physical Geography, including sketches of the topography, botany, climate, geology, and mineral resources; etc., by J. W. Foster, LL. D., Chicago (S C. Griggs and Company), 1869.

† This and the mention of the "isolated patches" of "crystalline rocks" of Fourche Cove in the same volume should have been noticed in Chapter II. on general literature, but Foster's work was not seen by the writer until after that chapter had passed through the press.

like the Iron-Mountain region of Missouri, Magnet Cove of Arkansas, and perhaps the Washita Mountains of Texas, the Black hills of Nebraska, and the Central Plateau of Colorado. No form of vegetable life, at that time, clothed the slopes of the hills, no forms of animal life roamed through the valleys, and even the waters were tenantless. It was emphatically a petrified continent, rigid and stony."

In a foot-note to this statement Foster writes: "This generalization was made by the writer (Foster) as far back as 1851, and was communicated to the American Association for the Advancement of Science, at the Cincinnati Meeting of that year." *

On page 265, under the head of "Azoic System" Foster states: "In Missouri and Arkansas there are isolated patches of these rocks, which appear to have been islands in the old Silurian sea, and it would seem that portions of the region occupied by the Rocky Mountains served as the floor of the Azoic ocean, on which the purely sedimentary deposits were formed." * * *

Kunz.—In 1885 Geo. F. Kunz read a paper before the American Association for the Advancement of Science at the Ann Arbor Meeting † on "A Pseudomorph of Feldspar after Leucite (?) from Magnet Cove, Arkansas," in which he describes the mineral and gives the results of a chemical analysis by Dr. F. A. Genth and of a microscopic examination by Dr. G. P. Merrill. These examinations will be referred to again, but the point which is of importance here is the inference which Kunz draws from the occurrence of

* Foster does not seem to have included the Magnet Cove rocks in his earlier statements for in an abstract of an article by J. W. Foster and J. D. Whitney entitled "On the Azoic System, as developed in the Lake Superior Land District" (Proc. A. A. A. S., Fifth Meeting, 1851, p. 7) the following sentence appears: "From the detailed explorations of Mr. Ch. F. Mersch, communicated to them, (Foster and Whitney) and which they proposed soon to publish, there could be no doubt that the Missouri iron region belonged to the same system of upheaval (as the Lake Superior region), and occupied the same relation to the Silurian System." In this article Foster makes no note of any Azoic region south of the Missouri iron region.

† Mineralogical notes by Geo. F. Kunz., Proc. A. A. A. S., Vol. XXXIV., Ann Arbor Meeting, 1885. Salem, Mass., 1886, p. 243. Also in the Am. Jour. Sci., Series 3, Vol. XXXI. 1886, p. 74.

these pseudomorphs. He says: "Heretofore leucite has never been observed in this locality, but if this proves to be an alteration from that mineral, leucite may yet be found in its unaltered form and in considerable quantity, judging from the abundance of pseudomorphs forthcoming." This is the first suggestion that was made of the possible occurence of a leucitic rock at Magnet Cove, but shortly after, in the year 1887, Rosenbusch published the statement already quoted (page 17) in which he suggests the probability that the leucitic rock is connected with the eleolite syenite which occurs in that region.

Comstock.—Few statements are made by T. B. Comstock* regarding the igneous rocks of the Cove, but he mentions many minerals in the text and gives a list at the end of the volume in which the occurrence of a large number of minerals in this region is recorded.

II. PETROGRAPHIC DESCRIPTION OF FELDSPATHIC ROCKS.

A. Eleolite Syenite.

1. Eleolite Mica Syenite (Cove type).

This rock in a fresh condition seldom occurs over a large area, but it is almost invariably partially or completely decomposed. In a few places, however, where it has been somewhat protected by the overlying deposits and where it is not as coarsely crystalline as usual it has preserved its structure and forms a beautiful example of a syenite in which eleolite has almost completely replaced the orthoclase.

It is a very coarsely crystalline rock in which the individual minerals often reach many centimeters in size. Thus for example weathered specimens of biotite (protovermiculite) have been found which are 20 to 30cm (8 to 12 inches) in diameter and 8 to 10cm (3 to 4 inches) in thickness. Eleolite, schorlomite and apatite crystals which correspond in size to the protovermiculite also occur imbedded in the decomposed rock.

The rock is a hypidiomorphic granular mixture of eleolite,

* Annual Report of the Geological Survey of Arkansas for 1887, Vol. I., pp. 81 and 82.

garnet (schorlomite and melanite), pyroxene and biotite, with large quantities of apatite, magnetite, titanite and ilmenite. It has a general pinkish color with dark colored spots which have a greenish hue due to the pyroxene and slightly decomposed biotite. As has already been stated the grain of the rock varies very much, ranging from exceedingly coarse to comparatively fine, but the rock is in each case characterized by the presence of eleolite and biotite and by the almost complete absence of feldspar.

In regard to the microscopic structure there is little to be said for in most cases the rock is too decomposed to allow of sections being made. Sections have, however, been cut from the finer grained, dike-like masses in which the physiography of the individual minerals could be studied.

Eleolite occurs in large allotriomorphic masses which only rarely show any indication of a crystalline form. It varies from a flesh-red to an oily yellow or brown and not infrequently assumes a decidedly gray color. It has the characteristic oily lustre from which the mineral derived its name and shows the usual want of distinct cleavage.

Microscopically the eleolite is seen to be, in most cases, bounded by the older constituents of the rock but in a few cases it is idiomorphic and appears as short hexagonal prisms. It weathers easily; in fact decomposition has in most cases gone so far that it is extremely difficult to obtain a section of the rock at all.

The eleolite, like many of the other constituents of this rock, occurs in loose masses in the soil. Occasionally rounded pieces several centimeters in diameter have been found. These masses are usually of a pink or gray color and are translucent to semi-transparent. They are known as *sun-stones* and have been cut for ornaments.

Eleolite was observed at an early date at Magnet Cove but all the earlier writers called it red feldspar* and it was not until C. U. Shepard saw a specimen of it that it was called by its right name. Shepard in a foot note to his article on the new

* See Featherstonhaugh's and other reports.

minerals from Magnet Cove* makes the following statement: "The elæolite with which this (schorlomite) and the foregoing species (ozarkite and arkansite) are found, and which had been called a compact red feldspar, is a remarkably well characterized variety; is perfectly fresh and unaltered, forming a grayish flesh-red, oily, translucent mineral. Its sp. gr.=2.60. H.=6.0. It is fusible into a colorless glass and in a state of powder at once forms with warm nitric acid, a flesh-colored jelly."

In 1853 J. Lawrence Smith analyzed the eleolite from Magnet Cove and it is probable that his material was obtained from the eleolite mica syenite. Smith describes the mineral in his article† as having a hardness of 6.0; specific gravity, 2.65; color, flesh-red; lustre, greasy; structure, massive. The chemical composition is expressed by the following analysis:—

Analysis of eleolite (Smith and Brush.)

SiO_2	44.46
Al_2O_3	30.97
Fe_2O_3 and FeO	2.09
CaO	0.66
K_2O	5.91
Na_2O	15 61
Ignition	0.95
Total	100.65

Smith states that the mineral examined was furnished by Mr. Markoe, of Washington, and was the specimen from which the ozarkite, analyzed and described in a previous paper‡, was obtained.

Orthoclase occurs in much decomposed crystals of which it has been impossible to study the microscopic structure. They are often 5 or 6mm in diameter but are not frequent in the rock. They are older than the eleolite and are idiomorphic as regards it.

Biotite appears under the microscope in large sections and is of a very light reddish or brownish yellow color when seen in non-polarized, transmitted light. The color is not uniformly distributed over the whole crystal but appears in spots and

* Am. Jour. Sci. Series 2, Vol. II., 1846, p. 253.

† Re-examination of American Minerals, Part III., by J. L. Smith, M. D., and George J. Brush, Ph. B. Am. Jour. Sci, Series 2, Vol. XVI., 1853, p. 371.

‡ Re- examination, etc, Part II. Am. Jour. Sci. Series 2, Vol. XVI., 1853, p. 50.

blotches, a peculiarity probably due to the beginning of decomposition. The mineral is quite pleochroitic with a variation in color between light yellow and reddish brown; the darker color being present, as usual, when the cleavage cracks of the biotite are parallel to the longer diagonal of the lower nicol. In convergent polarized light a black cross appears in sections which are approximately parallel to the cleavage-planes and in most cases the cross remains closed during a complete revolution of the stage. In some instances it opens slightly, but in no case has an angle of more than 2° or 3° been observed between the hyperbolas.

These characteristics, when taken in connection with Dr. König's analysis of protovermiculite* which is formed by the more complete alteration of this mica, indicate that the mica was originally biotite. This may be more clearly seen from the following considerations: if König's analysis be recalculated substituting for some of the water the potassium which it has replaced and rejecting the rest of the water the following figures result:—

Analyses of fresh and decomposed biotite.

CONSTITUENTS.	I. Protovermiculite, Magnet Cove.	II. No. 1. recalculated.	III. Biotite, Mt. Vesuvius.
SiO_2	33.28	39.80	39.75
Al_2O_3	14.88	17.80	15.99
Fe_2O_3	6.36	7.60	8.29
FeO	0.57	0.70	.....
MgO	21.52	25.74	24.49
CaO	.....	.....	0.87
K_2O	.....	8.36	8.78
H_2O (cryst.)	3.36	.....	0.75
H_2O (hydr.)	20.54	.....	.....
Total	100.51	100.00	98.92†

* Proc. Acad. Nat. Sci. Philadelphia, 1877, p. 277; also Am. Jour. Sci. Series 3, Vol. XVI. 1878, p. 152.

† In this analysis as quoted by Dana (l. c.) 0.10 gangue is noted and the total of the analysis is given as 98.62 while it should be 99.02 if the constituents are all correctly quoted.

I. Protovermiculite Magnet Cove, analyzed by König (loc. cit.).

II. Protovermiculite recalculated as described above.

III. Biotite, Mt. Vesuvius, analyzed by Bromeis. (Pogg. Annalen, Band LV., p. 112. Cited from Dana's System of Mineralogy, 1868, p. 305).

It is evident from the above analyses that the composition of the protovermiculite becomes that of a normal biotite when these recalculations are made, as is shown by comparing it with an analysis of biotite from Mt. Vesuvius.

The biotite in the solid rock is usually found to be altered about the edges and to have become greenish in color. Such a change of color without any alteration in the optic properties is mentioned by Rosenbusch.* It is seldom that the crystals show sharp edges but they are usually frayed out and broken.

Garnet appears in this rock in two varieties. The older of these consists of small idiomorphic crystals which under the microscope show a zonal structure the character of which is very distinctly brought out by the strong contrast between the reddish brown centers and the light yellow exterior bands. These alternations of color often recur several times in one crystal and hence it is seen to be made up of concentric bands. These crystals are melanite in which varying amounts of iron and titanium have caused a variation in color. They include apatite and biotite, but are idiomorphically bounded when they come in contact with the diopside and eleolite. Like all the garnets observed in these rocks they show no optic anomalies.

The garnets of the younger generation are entirely without crystal form and are bounded by the eleolite as well as the diopside and biotite. They are of a very dark brown color and are filled with inclusions of all the other minerals. They are perfectly homogeneous and show no zonal structure like the preceding variety. From their deep brown color and their want of crystal form it seems probable that they are richer in titanium and iron than the melanite and belong to the variety schorlomite. They fill in the spaces between the other minerals and it is not uncommon to find them in direct contact with the melanite, apparently forming a continuation of it.

* Physiographie, Vol. I., p. 435.

Schorlomite occurs principally in the large rounded masses associated with protovermiculite, magnetite and other minerals from this rock. It is probable that these masses of schorlomite had their origin in the igneous rock, but it is possible that they are metamorphic minerals formed by the contact of the igneous rock with the calcite which occurs in this region. (See chap. VIII. II. B.)

Schorlomite forms rounded masses of a bluish black color and is characterized by its want of crystal form and the pavonine tints which are generally present on its surface. It has probably never been found in crystals, although Shepard (see below) supposed that he had seen such. Zonal structure and concentric shells of different colors or shades are often observed. The rounded masses are usually penetrated by apatite prisms and occasionally a fragment of a mica crystal is imbedded in one of them. It resembles very closely the darker varieties of melanite which occur in this region, but is distinguished from that mineral by its bluish black color and iridescence.

The mineral was first described in 1846 by C. U. Shepard * who named it *schorlomite* from its resemblance to schorl or black tourmaline. Shepard found some small crystals which he considered identical with the massive material which he had had tested chemically and he therefore describes schorlomite as follows:—

"Primary form. Rhomboid. Dimensions unknown.

"Secondary form. Hexagonal prism, with lateral edges truncated by narrow and brilliant planes. Cleavage indistinct. Fracture conchoidal. Surface of the broader planes rather dull, of the narrower ones smooth and brilliant. Lustre vitreous. Color black. Streak grayish black, with a tinge of lavender-blue. Tarnished with blue and pavonine tints, thus causing it to resemble specular iron, (for which substance it has been mistaken.) It also resembles some varieties of bluish black, massive, or imperfectly crystallized, tourmaline.

"Hardness=7.0 to 7.5. Specific gravity=3.862."

* On Three New Mineral Species from Arkansas and the discovery of the Diamond in North Carolina by C. U. Shepard, Am. Jour. Sci., Series 2, Vol. II., 1846, p. 249.

From a qualitative chemical examination Shepard concluded that the mineral contained "silica, yttria, thorina (?), oxide of iron and water, and no oxide of cerium or lanthanum." He suggests that the mineral approaches in some of its properties allanite and gadolinite but is sufficiently different to deserve a new name. Shepard states that the mineral occurs in a specimen containing ozarkite and that the crystals are very minute, but that large, rough pieces of it occur with the large eleolite masses and that the former are often penetrated by the gangue until in some cases less than half the crystal consists of the pure mineral.

In 1849 two papers appeared independently, both showing that Shepard's idea of the chemical constitution of the mineral was incorrect. C. Rammelsberg's paper was entitled "Ueber die Zusammensetzung des Schorlamits * eines neuen titanhaltigen Minerals." †

He reviews Shepard's description of the mineral and then gives two analyses which are as follows :—

Analyses of schorlomite. (*Rammelsberg*).

Constituents.	a.	b.
SiO_2	27.85 ($+TiO_2$)	26.09
TiO_2	15.32	17.36
FeO	23.75	22.33
CaO	32.01	31.12
MgO	1.52	1.55
Total	100.45	98.95

He states that titanite which contains this quantity of titanium only contains half as much silica and a quarter as much lime.

J. D. Whitney's paper was entitled "Examination of three new mineralogical species proposed by Prof. C. U.

* Rammelsberg changed the spelling from schorlomite to schorlamite, probably at first unintentionally. Quenstedt (Handbuch der Mineralogie, 3 Auflage, 1877, p. 440) follows Rammelsberg's spelling, but Naumann-Zirkel and most other German and English authors follow the spelling of Shepard.

† Pogg. Ann. Band LXXVII., 1849, p. 123.

Shepard."* Whitney remarks that there are evidently two varieties of schorlomite, one colophonite and the other an amorphous mineral. He gives his attention especially to the latter and describes it as follows:—

"Specific gravity 3.807; hardness 7.5.

"Black, opaque, vitreous, tarnishes with pavonic tints; conchoidal fracture." The mineral was analyzed by him in connection with Mr. Crossley with the following results:—

Analyses of schorlomite. (*Whitney and Crossley*).

Constituents.	a.	b.	c.
SiO_2	27.89	25.66	25.14
TiO_2	20.43	22.10	.....
Fe_2O_3 (MnO)	21.90	21.58	.....
CaO	30.05	29.78	.....
Total	100.27	99.12	.....

Whitney states that he does not believe that this mineral is schorlomite and suggests for it the name *ferro-titanite*. He mentions the similarity of its constitution to that of titanite and of lime-iron garnet.

An analysis which was first published in 1850 in the third edition of Dana's Descriptive Mineralogy,† was made by Crossley and is as follows:—

Analysis of schorlomite. (*Crossley*).

SiO_2 (+TiO_2)	26.36
TiO_2	21.56
Fe_2O_3	22.00
CaO	30.72
MgO	1.25
MnO	Trace.
Total	101.89

In 1851 Rammelsberg published a second paper entitled "Mineral Analysen—Schorlamit—"‡ in which he reviews his first paper and that of Whitney and gives in full his first analyses.

* Boston Journal of Natural History, Vol. VI., 1849, p. 42.

† Descriptive Mineralogy by J. D. Dana, Third Edition, 1850, p. 692.

‡ Pogg. Ann. Band LXXXV., 1852, p. 300.

and those of Whitney and Crossley. He had in his first analyses considered all the iron as protoxide while Whitney and Crossley considered it all sesquioxide. Rammelsberg made a new determination by smelting the mineral with borax glass in a closed vessel with gold chloride. He obtained the following results:—

Analysis of schorlomite. (*Rammelsberg*).

SiO_2(dif.)	25.24
TiO_2	22.34
Fe_2O_3	20 11
FeO	1.57
CaO	29.38
MgO	1.36
Total	100.00

Specific gravity, 3.827.

He then obtained approximately the same formula as that found by Whitney.

In 1851 Whitney published another paper entitled "Analyses of C. U. Shepard's new minerals."* In this he gives no new analyses and simply reiterates the statement that as the mineral which he analyzed differs so greatly from that described by Shepard it should be called *ferrotitanite* and that the name schorlomite should be reserved for the real "hydrous silicate of yttria, thorina and oxide of iron."

Phillips Mineralogy of 1852† under the heading "Schorlomite—Ferrotitanite; Whitney," makes the following statement: "This mineral differs much in external characters and in chemical composition from the mineral described by Prof. Shepard as schorlomite."

In 1877 Knop‡ analyzed the schorlomite from Magnet Cove with the following results:

Analysis of schorlomite (*Knop*).

SiO_2	26.10
TiO_2	20.52
Fe_2O_3	21.95
CaO	29.35
MgO	1.47
Total	99.39

* Proc. Boston Soc. of Nat. Hist., Vol. III., 1851, p. 96.

† Elementary Introduction to Mineralogy by the late Wm. Phillips—New Edition by H. J. Brooke and W. H. Miller; London, 1852, p. 297.

‡ Zeit. für Kryst., Band I., 1877, p. 58.

He states that in the specimens from Magnet Cove, Ark., it occurs intergrown with melanite and can easily be mistaken for it.

Rammelsberg states * in reference to Knop's analysis that it is very similar to his own and that if part of the TiO_2 is considered as Ti_2O_3 an atomic relation similar to that of garnet is obtained.

It is evident from the numerous analyses and descriptions reviewed above that a great difference of opinion has existed in regard to the composition and properties of schorlomite. This is in a great measure due to the lack of similarity in the material examined by the various authors. Melanite resembles schorlomite very closely and is frequently intergrown with it so that in some cases a mixture of these two minerals and in other cases the pure schorlomite was analyzed.

It is evident, however, from the above analyses that a silicate of titanium, iron and lime having approximately the garnet formula, $R_3''(R_2''')Si_3O_{12}$, exists and is found in considerable quantities at Magnet Cove, but that this mineral is often more or less mixed with the iron-lime garnet, melanite.

Pyroxene appears under the microscope as the light green, almost colorless, non-pleochroitic variety diopside already described in several instances. In this rock it is precisely identical with that described later under eleolite garnet syenite. (See this chapter, II. A. 2).

Titanite occurs in small sulphur-yellow crystals which seldom exceed two or three millimeters in diameter. These

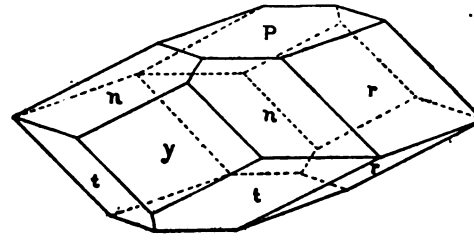


Fig. 11. *Titanite from eleolite mica syenite (Cove type).* Scale—30:1.

are exceedingly brilliant and have a very sharply defined crystal

* Handbuch der Mineralchemie, 1875, Ergänzungsheft zur zweiten Auflage, 1886, p. 201.

form. They are nearly equally developed in the directions of the vertical and ortho-axes but are somewhat thinner in the direction of the clino-axis. They are quite unlike those described by Genth from the eleolite eudialyte syenite (See this chapter, II. A. 4). One exceptionally perfect crystal (Fig. 11) bounded by the faces* $P=0P(001)$; $r=P\breve{\infty}$ (011); $n=\frac{3}{2}P\breve{2}$ (123); $y=+P\bar{\breve{\infty}}$ (10$\bar{1}$) and $t=-2P\breve{2}$ (121) gave the following angles when measured upon a reflection goniometer :—

Measurements of titanite angles.

	Measured.	Calculated.
$n : y$ — (12$\bar{3}$) : (10$\bar{1}$) —	38° 20′	38° 16′
$n : t$ — (12$\bar{3}$) : (121) —	71 22	71 20
$y : p$ — (10$\bar{1}$) : (001) —	59 56	60 17
$r : y$ — (011) : (10$\bar{1}$) —	65 25	65 30
$r : n$ — (011) : (123) —	27 05	27 14
$r : t$ — (011) : (121) —	44 17	... ...

In thin sections this mineral behaves as usual and requires no special mention.

Ilmenite appears with jagged and irregular contours in very large crystals. It generally shows a purplish color with the characteristic bands of a lighter shade running through it. In these rocks it seldom shows a border of leucoxene which would naturally be expected to appear strongly marked on account of the decomposition which has occurred.

Magnetite occurs frequently in grains and in crystals but is much more plentiful in some localities than in others. The occurrence of magnetite in the form of *lodestone* has already been mentioned and the connection of the latter with the magnetite in this rock has been explained in the preceding chapter (p. 180). The lodestone has been known from the earliest times and was mentioned by both Schoolcraft and Bringier and it is from this mineral that the locality received its name of Magnet Cove. It has been mentioned by all who have described the cove and many of the writers have supposed it to be merely the outcrop of an enormous subterranean deposit of iron ore.

* The position in which the crystal is placed is that suggested by G. Rose and adopted by Naumann, Bauer, Rosenbusch, etc., and not that of Des-Cloizeaux which is followed by Schrauf, Dana, etc.

Owen* says of the magnetite: "On the east part of Section 20, there is a great bed of magnetic iron ore, some of which exhibits polarity. It is not exposed in a high hill or mountain, as in Missouri, but is on the same level with the cultivated fields adjoining, occupying a superficial area of the immediate surface of about eight acres; the ground over this area being exclusively covered with fragments and blocks of magnetic iron ore occasionally mixed with lodestone. Beneath the surface it extends to an unknown depth. It has been penetrated from four to five feet without finding any change of the material, except that the lodestones seem to be more abundant on the surface.

"An analysis has been made of the magnetic iron ore with the following result:

Analysis of lodestone. (*Owen*)†.

Peroxide of iron (Fe_2O_3) †	67.20
Protoxide of iron (FeO)	24.46
Alumina (Al_2O_3)	0.45
Manganese (MnO)	0.80
Lime, magnesia and loss	2.19
Titanic acid (TiO_2)	1.20
Moisture (H_2O)	1.00
Insoluble matter	3.20
Total	100.00

"The lapping of the arable land on the margin of the magnetic iron ore conceals its relation to the adjacent rocks; but from the minerals ploughed up in the fields on the south and southeast, the magnetic iron ore seems to be surrounded, in part at least, with mica slates. Along with the large flakes of this mineral, brought to the surface by the plough, are beautiful crystals of augite, and black garnets."

Comstock ‡ suggests that the magnetite may be due to the reduction of a limonite similar to that occurring nearly due north of Magnet Cove at Blocher.

The masses of lodestone are of a dull black or brown

* Second Report of a Geological Reconnoissance of Arkansas, etc., p. 104.

† The symbols and heading are not given in the original analysis.

‡ Vol. I. of the Annual Report of the Geological Survey of Arkansas for 1887, p. 82, also p. 268.

color and their surfaces are usually smooth and rounded and not infrequently show the so-called "blisters" or botryoidal protuberances. These resemble externally small air bubbles inclosed within the mass, but they are solid and of uniform substance with the rest of the mineral and were formed by an unequal weathering of the surface. The mineral has a conchoidal fracture, metallic lustre and black color. It is strongly magnetic and in most cases polarized. In some specimens the magnetism is strong enough to hold up four shingle nails in a line.

The lodestone appears to be without any crystal form of its own. Specimens of lodestone have been found which present somewhat the appearance of pseudomorphs after pyrite but in no case could this apparent similarity be substantiated by crystallographic measurement.

One piece of lodestone showed a pseudomorphic crystal imbedded on one side. The crystal is of a long columar form and shows distinct though imperfect truncations at both ends. The prism faces, if such they be, make an angle of about 123° with each other and show the existence of a pinacoidal face between them. The crystal is 40mm long and presents the appearance of a pseudomorph of magnetite after hornblende.

In order to determine whether or not phosphorus was present in considerable quantities in the lodestone a test was made by the chemist of the Survey upon 1.5 grams of the mineral. No precipitate nor even coloration with ammonic molybdate was observed and it may therefore be assumed that the lodestone is free from phosphorus.

Pyrite occurs in considerable quantities.

Apatite occurs in two forms; first in large hexagonal columns, often as much as 15cm in length and 2.5cm in diameter, of a pure white or slightly yellowish color. The prism faces $(10\bar{1}0)$ are generally sharp and well defined, but with the exception of an indistinct pyramid $(10\bar{1}1)$ and the basal plane (0001) no truncations were observed about the ends of the principal axis. These large prisms are often found penetrating the schorlomite and magnetic iron ore. The second variety consists

of a mass of fine needles in radiate groups. These form masses imbedded in the schorlomite and eleolite and were at one time mistaken for Shepard's ozarkite. *

The writer made a partial analysis of this radiate mineral in order to determine whether it was a chlorine or fluorine apatite, with the following results:—

Analysis of apatite.

CaO	54.55
P_2O_5	42.00
Fl (by dif.)	4.16
Cl	0.02
$Fe_2O_3+Al_2O_3$	0.61
Ignition	0.42 †
Sum	101.76
Oxygen	1.76
Total	100.00

Although this analysis makes no claim to great accuracy it is evident that the mineral in question is a pure fluorine apatite.

Thomsonite (*Ozarkite*) was first announced from Magnet Cove by C. U. Shepard in 1846 and described by him under the name ozarkite in a paper entitled "On three new Mineral Species from Arkansas and the Discovery of the Diamond in North Carolina." ‡ The material was obtained from the Rev. E. R. Beadle, a resident of New Orleans, who collected it during a journey through the Hot Springs region. Shepard gave the name *ozarkite* to this mineral because he supposed Magnet Cove to be situated in the Ozark Mountains.§

* See Am. Jour. Sci., Series 2, Vol. IX., 1850, p. 430.

† Regarding the determination of water by ignition when fluorine is present compare "Ueber die Zusammensetzung des Apatits" Inaugural-Dissertation von J. L. Hoskyns-Abrahall, München, 1889, p. 6.

‡ Am. Jour. Sci., Series 2, Vol. II., 1846, p. 249.

§ This is a very common error made by people, both in and out of the state, but it should be distinctly understood that the Ozark Mountains constitute a range of mountains in southern Missouri, but which also extend into the northern part of Arkansas. The name Ozark Mountains has, however, occasionally been applied to the mountains about Hot Springs and it is to this use of the name that the confusion is due.

Shepard describes the mineral as follows:—

"Massive. Composition, laminae (confused) nearly impalpable. Fracture uneven.

"Lustre feeble, vitreous to resinous. Color white (rarely bluish) to flesh-red. Streak white. Translucent.

"Brittle. Hardness 4.5. Specific gravity, 2.746."

He then describes it behavior before the blowpipe and mentions that it dissolves freely in hydrochloric or nitric acid without effervescence, but forms a deposit of silicic acid. He says, "It appears to be a siliceous hydrate of lime and yttria possibly also having traces of thorina." He describes its occurrence in the following words: "It occurs diffused in irregular veins and ovoidal masses (about one-fourth of an inch in diameter) through a flesh-colored elæolite, from which mineral however, it is constantly separated by a thin layer of red jasper-like substance, which is obviously distinct from the two minerals it tends to separate; and may itself be an undescribed species."

In 1849 J. D. Whitney published an article on C. U. Shepard's new minerals* in which he mentions ozarkite and states that it does not contain yttria and thorina but is a silicate of alumina and lime with a little soda and is probably scolecite.

J. D. Dana in 1850 published a note "On the Ozarkite of Shepard"† in which he mentions Whitney's discovery of its likeness to scolecite and then says that several specimens were examined by G. J. Brush and were found to consist largely of phosphate of lime. He says, "They have often the radiated appearance of a zeolite with acicular crystallizations; but after Mr. Brush's discovery of phosphoric acid the writer (Dana) found by means of a glass that the acicular prisms were in fact hexagonal prisms of apatite. Other large prisms were also found in some specimens. The acicular mesotype-like mineral is associated with another of a mealy character and in part sub-lamellar, which may be a zeolite as observed by Whitney."

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* Jour. Boston Soc. Nat. History, Vol. VI, 1849, p. 42, and also later in Proc. Boston Soc. Nat. History, Vol. III., 1851, p. 96.

† Am. Jour. Sci. Series 2, Vol. IX., 1850, p. 430.

In 1851 under the head of Mineralogical Notices* Dana published a note stating that Prof. Shepard had re-examined ozarkite with the following results †:

Analysis of Ozarkite (Shepard.)

SiO_2	40.91
Al_2O_3	15.75
$Ca_3(PO_4)_2$	4.17
CaO	4.52
H_2O	15.10

He remarks that this removes the mineral from scolecite with which Whitney wished to unite it. Dana says that the results of Brush, Whitney, and Shepard are too widely different to indicate that any simple mineral was examined.

Two years later J. Lawrence Smith and George J. Brush published a paper entitled, "Re-examination of American Minerals, Part II," ‡ and under the sub-head "Ozarkite an Amorphous Thomsonite" they show that the mineral in question is truly a zeolite and that it had been confused with apatite in the determinations that had been made. They state that the material for their analysis was obtained from Mr. Markoe and that the substance occurs in veins and masses in eleolite. They give its color as white; structure, granular to compact; hardness, 5; specific gravity, 2.24 (Shepard), and state that it gelatinizes with HCl. Two analyses gave the following results:—

Analyses of ozarkite (Smith and Brush).

CONSTITUENTS.	a. —	b. —	Theoretical. $RSiO_4 + 3Al_2SiO_5 + 7H_2O$.
SiO_2	36.85	37.08	37.80
Al_2O_3	29.42	31.13	31.50
Fe_2O_3	1.55		
CaO	13.95	13.97	13.00
Na_2O	3.91	3.72	4.80
H_2O	13.80	13.80	12.90
Total	99.48	99 70	100.00

* Am. Jour. Sci. Series 2, Vol. XII., 1851, p. 218.

† Proc. of Am. Ass. Adv. Sci. 4th Meeting. Held at New Haven, p. 322 (Cited after Am. Jour. Sci., loc. cit.).

‡ Am. Jour. Sci. Series 2, Vol. XVI., 1853, p. 50.

This is the same composition as that of thomsonite and the mineral was considered as a massive variety of that species.

The analysis gave the formula:—

$$RSiO_4+3Al_2\ SiO_5+7H_2O.$$

A special examination was made for phosphoric acid but none was found although some of the impure material, which had been previously analyzed, showed considerable quantities of it and proved to be a mixture of the zeolite with apatite.

In the continuation of that paper (ibid. p. 371) under the head of eleolite the statement is made that good radiated crystallizations of ozarkite (thomsonite) in eleolite had been obtained.

It is evident from the above quoted opinions and analyses that much confusion has existed in regard to what ozarkite really is, and it is evident that Brush in his first determination of the mineral in which he found phosphoric acid had before him one of the radiations of apatite already described (p. 220). It was, however, shown soon after by Smith and Brush that the mineral is really a zeolite which should originally have been identified with thomsonite and not made a separate species.

The large white rectangular columnar crystals which are found near this locality (Chap. VII. II. B. 2) are natrolite and not thomsonite (ozarkite) as is often supposed. The writer has not seen crystallized thomsonite from this locality.

Protovermiculite was one of the first minerals observed and recorded from Magnet Cove. Schoolcraft* mentions mica as being found at "Hot Springs of Washitaw" and describes it as follows, "the lamina are very small, extremely flexible, of a greenish yellow colour and admitting very little light through their broader faces." This is precisely the description of the protovermiculite from Magnet Cove, but no such material occurs at Hot Springs and therefore must have been carried there.

Bringier* says of this mineral: "Above the ore (lodestone) and not one hundred yards off, is an extensive bed of common talc (mica? Editors of Am. Journal Sci.); the leaves are of an extraordinary size, not less than five inches by seven."

* A View of the Lead Mines of Missouri, etc., p. 190.

* Am. Jour. Sci., Series 1, Vol. III., 1821, p. 26.

König * was the first to analyze and accurately describe this mineral and from its general similarity to vermiculite he called it *protovermiculite*. He described the mineral as occurring in large foliated plates and smaller prismatic crystals associated with apatite and black garnet. The structure is strongly micaceous, optically biaxial and probably monosymmetric. The angle of the optic axes is very small. Thin laminæ are flexible but not elastic. Color grayish green in interior of the plate but becomes yellowish silvery to bronze on the outside. Lustre submetallic. Touch somewhat unctuous. Specific gravity 2.269.

König's analysis has already been cited (page 211) but is here repeated.

Analysis of protovermiculite. (*König*).

SiO_2	33.28
TiO_2	Trace.
Al_2O_3	14.88
Fe_2O_3	6.36
FeO	0.57
MnO	Trace.
MgO	21.52
H_2O	3.36
H_2O (Hydroscopic)	50.54
Total	100.51

There is little to be added to this description. The only additional points of interest which have occurred to the writer are the facts that the plane of the optic axes is the symmetry plane (010) and that the plates of mica are often forced apart by thin, lens-shaped masses of calcite formed from the decomposition of the mineral itself.

Cancrinite is plentiful along the cracks of the eleolite but is of a secondary nature.

Calcite occurs in considerable quantities in the more decomposed rock.

The order of crystallization of the various minerals is as follows :—

* Protovermiculite, a new mineral species by G. A. König, Proc. Acad. Nat. Sci. of Phila., 1877, p. 267.

Iron ores, apatite, biotite, melanite, diopside, orthoclase, eleolite, schorlomite.

Chemical Composition.—The eleolite mica syenite was analyzed by the writer and gave the following composition, showing that it is distinctly different from the Diamond Jo and allied rocks to be described later.

Analysis of light colored eleolite mica syenite.

SiO_2	38.93	
TiO_2	1.62	
X (*)		
Al_2O_3	15.41	26.37
Fe_2O_3	5.10	
FeO	4.24	
FeS_2	0.89	
CaO	16.49	
SrO	Trace.	
MgO	5.57	
MnO	Trace.	
K_2O	1.78	
Na_2O	5.27	
Li_2O	Trace.	
Cl	0.02	
P_2O_5	0.35	
SO_3	0.00	
Loss on ignition	5.20	
Total	100.57	

The specimen analyzed was taken from one of the harder bands found in the bed of "the branch" north of J. F. Moore's house (See page 182).

In that portion of the Magnet Cove region which lies near Cove Creek but east of the limits of the Cove proper there occur large masses and areas of a dark brown, coarse-grained rock

* By X are represented the oxides of those earths which are insoluble in cold water after having been smelted with $KHSO_4$. Zr_2O_3, Ta_2O_3, etc., may be included under this head. Compare—Knop in the Zeitschrift f. Kryst, Vol. X., 1884, p. 58.—Beiträge zur Kenntniss d. Eruptivges. des Christiania-Silurbeckens by Lang and Jannasch, Christiania, 1886, pp. 39 and 113.—Einige Gesteine aus der Rhön, by E. Möller. (Neues Jahrbuch, f. Mineralogie, 1887). —Ueber den Monte Amiata und Seine Gesteine, by J. Francis Williams. (N. Jahrb. f. Mineral. Beil. Band V., 1887, p. 24.)—Gesammelte chem. Forschungen, by P. Jannasch, Band I., Göttingen, 1888, p. 176.

which resembles both the eleolite syenite (Cove type) and the members of the monchiquite and fourchite group.

It is hypidiomorphic granular with no tendency whatever towards a porphyritic structure and shows both by its occurrence and structure that it belongs to one of the older abyssal rocks and not to the intrusive dike type.

The minerals are more closely allied to those of the eleolite syenite than of the monchiquite group. The dark minerals are greatly in excess of the light colored ones and it is possible that this rock forms one of the more basic rocks in which the iron becomes such an important factor (See pp. 180 and 219).

The pyroxene is of the diopside type and is not the augite of the monchiquites. Olivine is wanting. Large biotite crystals which have been more or less completely altered to serpentine make up a large part of the rock.

Eleolite is present only in somewhat rare, partly decomposed crystals. In most cases it has been completely altered so that nothing more than a mass of strongly polarizing, decomposition products remain.

The ores of iron and titanium are present in great quantities and in some of the specimens examined they form a large per cent of the dark colored minerals. Pyrite is present in abundance. An analysis of the rock gave the writer the following results:—

Analysis of dark colored eleolite mica syenite.

SiO_2	36.51	
TiO_2	3.11	
X(*)	2.10	
Al_2O_3	8.22	25.03
Fe_2O_3	8.29	
FeO	3.31	
FeS_2	6.03	
CaO	18.85	
SrO	Trace	
MgO	8.19	
MnO	trace	
K_2O	1.08	
Na_2O	2.10	
Cl	0.03	

* For explanation of use of X, see page 226.

P_2O_5	(?)
SO_3	(?)
Loss on ignition	1.40
Total	99.22

When the iron (exclusive of pyrite), alumina and titanium are grouped together in both analyses the agreement is much more evident than when they are considered separately.

For convenience in comparing these two analyses with each other and with an analysis of the amphibole fourchite (monchiquite) from Magnet Cove (See page 226 and chap. VII. III. B) and typical specimens of ouachitite from elsewhere in Arkansas (See chap. XII.) the following table has been prepared.

Table of analyses of basic rocks from Arkansas.

CONSTITUENTS.	I. Light colored eleolite syenite.	II. Dark colored eleolite syenite.	III. Amphibole fourchite.	IV. Ouachitite.	V. Ouachitite.
SiO_2	58.93	36.51	43.50	36.40	38.07
TiO_2	1.62	31.11	2.10	0.42	.....
X(*)		2.10	.....	.....	.....
Al_2O_3	15.41	8.22	18.06	12.48	17.92
Fe_2O_3	5.10	8.29	7.52	8.27	14.06
FeO	4.24	3.31	7.64	4.59	
FeS_2	0.89	6.03	.....	.....	.....
CaO	16.49	18.85	13.39	14.46	11.70
MgO	5.27	8.19	3.47	11.44	8.87
K_2O	1.78	1.08	1.80	3.01	2.23
Na_2O	5.27	2.10	2.00	0.97	0.96
CO_2	.....	.....	.....	3.94	5.50
P_2O_5	0.35	.....	.....	1.04	.....
Cl	0.02	0.08	.....	.....	.....
H_2O (ignition)	5.20	1.40	1.22	2.36(†)	.....
Total	100.57	99.22	100.20	99.84	100.91

* For explanation of use of X, see page 226.

† This water determination was made directly.

1. Eleolite syenite (Cove type, light colored), analyzed by J. Francis Williams (p. 126).

II. Eleolite syenite dark colored, analyzed by J. Francis Williams (p. 127).

III. Amphibole fourchite, Magnet Cove. Long dike in S. W. ¼ section 18. (p. 185). Analyzed by W. A. Noyes (Chap. VII. III. B).

IV. Ouachitite (rich in biotite) 3 S., 20 W., Sec. 11, N. E. quarter of N. W. quarter. Analyzed by L. G. Eakins, (Chap. XII).

V. Ouachitite (poor in biotite), 1 N., 15 W., section 35, N. E. quarter. Analyzed by J. F. Kemp, (Chap. XII).

A comparison of the above analyses shows that it is not very clear from a chemical standpoint to which group the dark colored rock belongs for it is about as much like one as the other. If future investigations should tend to separate it from the eleolite syenite it would fall in the group of the peridotites free from olivine for its structure is such (hypidiomorphic granular) that it cannot be united with the hypocrystalline monchiquites.

2. *Eleolite garnet syenite (Ridge type).*

This rock is usually of a dark color and presents a decidedly oily appearance which is due not to the fineness of the individual crystals composing it, but to the characteristic fracture of both the eleolite and the garnet which form its chief constituents. It is very heavy and shows a great latitude in the relative amounts of eleolite and the dark colored components. In some cases the latter do not make up more than a quarter of the mass of the rock while in other cases they form as much as three quarters of the whole. Of these two varieties the former is naturally somewhat lighter in color than the latter, but, as has been stated, the general tone of the rock is dark.

Structure.—The rock is hypidiomorphic granular in its structure and never shows any tendency towards a porpyritic character. It is an abyssal rock and has the characteristic granitic structure of those rocks. The size of the individual crystals varies considerably, for in some cases they become several centimeters in diameter while in other cases they sink to microscopic dimensions.

Under the microscope the rock is seen to be made up of

a hypidiomorphic granular mixture of eleolite, melanite (schorlomite (?)) and diopside, with occasional biotite flakes and the usual accessory minerals.

Eleolite appears in oily looking, yellowish, flesh-colored or grayish masses showing no exterior form, but bounded by the pyroxene and garnet.

Under the microscope the mineral presents its usual appearance except that it is somewhat fresher than it is commonly found. In many cases, however, it has been much decomposed and shows a formation of kaolin, cancrinite and other decomposition products. It often includes the minerals of older formation and contains also lines of gas-pores and minute cavities containing some liquid. The liquid in these pores often contains stationary bubbles but in no case have moving ones been observed.

Orthoclase is entirely wanting in the typical rock.

Pyroxene is of a light yellowish color and is very slightly, if at all, pleochroitic. The angle of extinction is large and together with the color and the lack of pleochroism makes it evident that the mineral is *diopside.* The mineral is very similar in cleavage, etc., to that already described (pp. 61-63). In these crystals, although there is no increase of color near the edge, the coloring matter is not uniformly distributed throughout the crystals but is more observable in some parts than in others.

Weathering is indicated by yellowish brown lines along the cleavage-cracks. The inclusions are such as are usually noticed in this mineral.

Garnet occurs in the form of black, shining grains of variable size. They are macroscopically distinguished from the other black minerals by their want of cleavage and their glassy fracture. Under the microscope the garnet usually has an idiomorphic form and appears as a yellowish brown, isotropic substance. It is usually decidedly zonal in its structure, although some cases have been observed where the crystal appears to be uniform throughout. Between crossed nicols the mineral remains perfectly isotropic and

even with a selenite plate no optic anomalies could be discovered. From its color and general appearance this garnet would appear to be melanite, but from the fact that it occurs in very close proximity to the beds where such large quantities of schorlomite are found it is possibly, in part at least, to be connected with that mineral. Some portions taken from a microscopic slide, when tested with ferrous sulphate in a bead of microcosmic salt showed only a very slight reaction for titanium, but it is more than probable that this element is not present in all the crystals in the same degree. It should be distinctly understood therefore that while this mineral is called *melanite* it probably includes *schorlomite* and perhaps *jivaarite* as well.

The relative ages of melanite and diopside are not perfectly clear, for in many cases the melanite is found included in the diopside, while in some cases the latter has an idiomorphic form where it comes in contact with the former. The result of observations on a large number of examples indicates, however, that the melanite is the older of the two minerals, but that their periods of formation were not far removed from each other. It is probable that the melanite was still forming when the diopside began to crystallize.

Biotite occurs in small quantities, but in the typical rock this mineral is very scarce. It is usually of a light green color and shows the beginning of alteration. It is negative and apparently uniaxial for white light.

Apatite is not common, but when it appears it forms comparatively large idiomorphic prisms. *Magnetite* occurs in idiomorphic forms and also in long rod-like crystals. *Ilmenite* occurs in irregular grains and is characterized by its purplish color, rough surface, and the systems of dark and light bands observed when it is examined in polarized light. It is occasionally found surrounded by a band of leucoxene. *Titanite* is not common and seems to have been replaced by the other titanium minerals present.

Cancrinite appears only as a secondary mineral and is usually found in the form of slender needles arranged about

the cracks in the eleolite. It is characterized as usual by its high double refraction and its effervescence with hydrochloric acid.

3. Miarolitic Eleolite Syenite.

This rock occurs in small areas at several points in Magnet Cove, as indicated on map IV. and mentioned in the general description. (See chapter VI.) The rock is so decomposed that at no place is it sufficiently fresh to allow of a minute macroscopic or microscopic investigation. Its mode of occurrence and its relations to the neighboring rock are also concealed for the same reason.

It generally appears at points where some of the small brooks have cut deep down into the overlying soil and seems to form a rock older than the eleolite syenite dike rock (Diamond Jo type) and the leucite syenite dike rock, in the neighborhood of which it is usually found.

It forms a coarse-grained, friable, yellowish brown rock which consists principally of feldspar and biotite with the remains of some other basic silicates. The eleolite appears to have been almost if not entirely decomposed. The rock contains many cavities into which the feldspar crystals extend and show by their perfect crystalline forms that these spaces were either originally empty or were filled with some late-formed mineral which has since been decomposed.

The feldspar appears in large (10 to 20mm) thick crystals somewhat tabular parallel to the clinopinacoid. They are bounded by the faces commonly found on orthoclase and are occasionally twinned according to the Carlsbad law. The great amount of kaolinization which has taken place prevents any microscopic study of these crystals.

On a close examination it appears that some eleolite has escaped the action of the elements and remains to indicate the original character of the rock. Biotite is the only one of the basic silicates which has withstood the weathering sufficiently to be recognized. Augite and hornblende, if they were ever present, are now entirely gone.

Pyrite seems to have been an important mineral in the

fresh rock for limonite now appears filling the spaces that were once occupied by the pyrite. In cases where the decomposition is not too far advanced the rock emits a strong odor of sulphuretted hydrogen (H_2S).

The rock, as appears from the above description, has been found in but a poor state of preservation and hence it has not been sufficiently studied to allow any definite classification of it to be made. It seems probable, however, that it was formed in considerable masses and constituted a miarolitic variety of the older or abyssal type of eleolite syenite.

B. Eleolitic Dike Rocks.

1. Eleolite Syenite Dike Rock (Diamond Jo Type).

The eleolite syenite dike rock possesses a holocrystalline, hypidiomorphic granular structure which often inclines to a trachytic structure.* In texture it varies between very wide limits. Some of it is fine-grained while other specimens show an extremely coarse-crystalline texture.

Macroscopically the orthoclase is by far the most important constituent of the rock. It occurs in large (5 to 20mm) allotriomorphic crystals, tabular parallel to the clinopinacoid and often shows a well defined external crystal form. These crystals give a decidedly trachytic appearance to the rock. (See page 85). They are of a slightly grayish white color, have a distinct cleavage and show a mother-of-pearl lustre on the basal cleavage-plane (001). The basic silicates are rare and appear as small, jet black, shining masses with an indistinct cleavage. The eleolite appears as grayish, waxy looking masses squeezed in between the feldspar crystals.

Under the microscope the rock is seen to be a hypidiomorphic granular mixture of orthoclase, eleolite (much decomposed), cancrinite and pyroxene.

Orthoclase is seldom fresh but appears as opaque, oblong sections which are the natural forms for crystals tabular parallel to the clinopinacoid to assume when they are cut exactly or nearly at right angles to the symmetry-plane.

* See plate 1. (Frontispiece.)

The cleavage-planes appear as distinct cracks and are emphasized by the kaolinization which has begun from them. Twin crystals are common and both the Carlsbad and Baveno laws have been observed. The optic axis angle is small—so small in fact that it would indicate that the mineral inclines more towards a sanidine than an orthoclase. The orthoclase is perfectly free from isomorphic mixtures of other feldspars and shows therefore no microperthitic structure. The inclusions are very plentiful and consist principally of kaolin and small gas cavities which are often arranged parallel to the vertical axis.

Eleolite can be macroscopically distinguished by its grayish color and somewhat greasy appearance. In some cases it has been so completely altered as to lose its characteristic lustre.

Under the microscope the eleolite appears both as idiomorphic and allotriomorphic crystals; when it comes in contact with the orthoclase the latter forms the boundary, but when it is imbedded in cancrinite its form is idiomorphic. Eleolite usually appears in thick, hexagonal prisms, not much longer than they are broad, which often measure 2 to 3mm in their greatest diameter. Cracks are common in sections parallel to the vertical axis, but the true cleavage-cracks have been observed only in sections parallel to the base. This cleavage is then seen to lie parallel to the hexagonal prism faces $(10\bar{1}0)$.

In some cases fresh specimens of eleolite have been observed, but in far the greater number of cases decomposition has taken place to such an extent that nothing but highly double refracting alteration products in the form of small needles and irregular plates can be found. The inclusions of gas are very common and are almost without exception in the form of oblong cavities arranged parallel to the vertical axis.

The eleolite, whether altered or not, is easily attacked by hydrochloric acid and forms a gelatinous silica which on drying is filled with small cubes of salt.

Cancrinite usually occurs in the spaces not occupied by orthoclase and eleolite and hence is seldom if ever found in idiomorphic crystals. It is often 0.5mm or more in size and appears in polygonal or triangular shaped sections which are clear and transparent and seldom show any indications of decomposition. The cancrinite is distinguished by its high polarization colors and strong double refraction. Even in thin sections these colors rise to orange and red of the first order and are very characteristic of the mineral, which might otherwise easily be mistaken for eleolite, which it resembles in many respects. The cleavage observed in some sections forms two sets of cracks at right angles to each other which appear to be nearly equally distinct. In other sections three systems of lines have been found which make angles of 60° with each other and correspond to a prismatic cleavage. In polarized light the extinction is found to lie parallel and perpendicular to the right angled cleavage cracks, thus showing that these lie parallel respectively to the base and principal axis. The index of refraction is lower than that of Canada balsam and therefore the surface of the section appears smooth. In sections at right angles to the principal axis a comparatively sharp, black cross appears around which is one wide ring. When this interference figure is tested with a mica plate, the negative character of the double refraction is easily established. If the sections are not perfectly basal but are slightly inclined the cross is found near one edge of the field, and two, or even three, rings appear.

There is always more or less doubt about the identity of a mineral where the external crystal form is wanting, and, therefore, in order to establish the character of this mineral more surely, it was tested microchemically, with the following results. A thin section of the rock containing this mineral was treated in the cold with dilute hydrochloric acid and this mineral effervesced slightly, but, when warmed a little, the effervescence became very rapid and took place from all parts of the crystal. As the acid dried the section became covered with gelatinous silica in which small cubes of salt were very numerous and perfectly formed. It is evident, therefore, that both in chemical as

well as optic characteristics this mineral is identical with *cancrinite*. The only minerals with which it might be confused are eleolite, hydronephelite and eudialite, from which it is easily distinguished by its strong double refraction, high interference colors and effervescence with hydrochloric acid; calcite, from which it is distinguished by its gelatinization and separation of salt cubes when treated with hydrochloric acid, and by its want of twinning lamellæ, decidedly lower interference colors, fewer, wider rings about the uniaxial cross, and the cleavage-planes parallel to the base and prisms; quartz, from which it is distinguished by its negative double refraction; the members of the scapolite group, from which it is distinguished by the carbon dioxide it contains. From minerals belonging to other than the tetragonal or hexagonal systems it is distinguished by its uniaxial interference figure.

Cancrinite sometimes occurs in long prisms imbedded in the feldspar and eleolite and occasionally shows a hexagonal form when cut at right angles to the principal axis. In these cases, as in the preceding, it is characterized by its high polarization colors. The cancrinite is usually clear and fresh and shows but few inclusions. It is highly probable that it is, in part at least, a primary mineral of this rock.

Pyroxene has been observed in large idiomorphic crystals which are generally of a dark green color. They show a decided pleochroism between various shades of green and their absorption is very strong. From its general characteristics it is evident that the pyroxene belong to the variety *ægirite*.

In some cases, also, a lighter colored, greenish pyroxene has been observed which has a comparatively large angle of extinction which is still larger for the substance in the center than for that about the outside. This may therefore be considered as belonging to the variety *diopside*.

Biotite occurs very rarely and when it appears presents no peculiarities of structure or optic properties.

Amphibole is entirely wanting in this variety of rock and in fact in all the syenitic rocks of Magnet Cove it is almost without exception replaced by pyroxene.

Sodalite occurs occasionally as an accessory mineral in some sections but is entirely wanting in others. It is idiomorphic in form and is usually elongated parallel to some one of its crystallographic axes so that it does not present a regular polygonal section. It is perfectly isotropic and shows no optic anomalies of any kind.

Titanite, magnetite and *pyrite* are present in very small quantities in some sections and are absent entirely in others. At best they play but a very small part among the constituent minerals of the rock. *Apatite* appears to be entirely wanting.

Decomposition and *alteration products.*—Among these are found secondary ægirite, secondary cancrinite, fluorite, calcite, hematite, kaolin and titanite.

Ægirite forms small radiate groups of minute, needle-like crystals such as have already been described in other rocks. (See page 80). They are evidently formed by the decomposition of primary ægirite or of other basic silicates.

Cancrinite appears in the form of a highly refracting, fine, fibrous decomposition product which has replaced a great deal of the eleolite. It is probably mixed with ranite and other alteration products. It is often in direct association with the primary cancrinite, but is of an entirely different form; the primary material is compact and uniform while the secondary shows very markedly its composite structure.

Fluorite forms small purple crystals imbedded in the rock and is also quite largely developed as a filling material in the seams. In the latter case it occurs in the form of thin, circular, or polygonal, purple masses which are often 3 to 5cm in diameter, but seldom exceed 2mm in thickness. These show an octahedral cleavage and are isotropic under the microscope. When heated in the dark they fluoresce with a greenish color and belong to the variety *chlorophane.* When the powder of this mineral is heated with sulphuric acid in a platinum crucible fluorine is readily given off, as is shown by the etching of a watch-glass placed over the top of the crucible. Besides the purple variety, fluorite often occurs in yellow or colorless trans-

parent crystals which are easily mistaken at first sight for calcite. The purple mineral has been mistaken for sodalite.

Calcite appears as a decomposition product of many minerals and is often found associated with the undecomposed material as well as with other alteration products. Its high double refraction and twinning lamellæ are very characteristic.

The calcite also occurs with the fluorite in the cracks of the rocks. It is distinguished from the light colored varieties of the latter by the fact that it effervesces easily with cold dilute hydrochloric acid. *Hematite* and *kaolin* are found as is usual in such rocks, and *titanite*, which may perhaps be better designated as leucoxene or titanomorphite, appears as the alteration of some titaniferous magnetite grains, which it encircles like a border.

An analysis of a specimen of this rock taken from newly quarried rock from the Diamond Jo quarry gave the following figures. The analysis was made by the Survey, R. N. Brackett and J. P. Smith, analysts.

Analysis of eleolite syenite dike rock.

SiO_2	53.38
Al_2O_3	20.22
Fe_2O_3	1.56
FeO	1.99
FeS_2	1.77
MnO	Trace.
CaO	3.29
MgO	0.29
K_2O	6.21
Na_2O	7.89
H_2O, CO_2	3.43
Total	100.03

This analysis shows that the rock, although not as basic as the coarse-grained eleolite syenites of the Cove type, is by no means as acid as the pulaskite or eleolite syenite of the Fourche Mountain region.

2. *Eleolite eudialyte syenite.* (*Pegmatite*).

This rock apparently occurs as a dike in the Paleozoic rock but owing to the poor exposures of rock about its borders, its

size and direction are somewhat indefinite. It is found at the point where the Hot Springs-Malvern road crosses Cove Creek and also on the north bank of the "Branch" a few hundred yards from where it empties into Cove Creek.

The rock shows a great variation in the size of its constituents. In some cases these become extremely large, occasionally reaching a diameter of as much as 15cm (6 in.), while in other cases they are not more than a millimeter in diameter.

The coarse-grained variety consists of a pegmatitic combination of orthoclase (microcline) in huge idiomorphic crystals, ægirite in long, beautifully terminated prisms, eleolite, eudialyte, astrophyllite, titanite, manganopectolite, thomsonite (ozarkite), natrolite, and other decomposition products of eleolite. This rock is so altered by weathering that it is difficult to say much about its structure except that in a general way it forms a coarse, pegmatitic dike. A description of the microscopic structure of this rock is entirely out of the question on account of the size of its constituents and the decomposition which has taken place. The coarse-grained rock is mixed with finer grained varieties, which are of a dark gray color and in many cases become very fine-grained. In these fine-grained rocks orthoclase or microcline, eleolite, ægirite, eudialyte, etc., occur, and the structure becomes hypidiomorphic granular.

Orthoclase or *microcline* often occurs in very large tabular crystals some of which have been found to be 10 to 15cm in greatest diameter and 1.5 to 2.0cm in thickness. These have only been observed as simple crystals. Their character as microcline was first observed by Des Cloizeaux, and described by him in his article * on microcline. The description is so meager that it is impossible to be absolutely sure that the specimen analyzed was identical with those from this locality, but, since this rock is the only one from which large, comparatively free feldspars can be obtained and is the rock which contains the large ægirite crystals sent in such quantities to Europe, it is more than probable that the mineral which Des Cloizeaux described came from this rock.

*Mémoire sur l'existence, les propriétés optiques et crystallographiques, et la composition chimique du microcline nouvelle espèce de feldspath triclinique à base de potasse, par M. Des Cloizeaux. Comptes Rendus. Tome 82, 1876, p. 885.

The analysis which was made by Pisani and published by Des Cloizeaux, (l. c. p. 891), is as follows:—

Analysis of microcline. (*Pisani*).

SiO_2	64.30
Al_2O_3	19.70
Fe_2O_3	0.74
K_2O	15.60
Na_2O	0.48
Loss on ignition	0.35
Total	101.17
Specific gravity	2.54

The inclination of the base (001) to the brachypinacoid (010) was kindly measured by Prof. J. F. Kemp, of Cornell University, upon a reflection gonimeter and gave the following angles:—

M : P	010 : 001 =	90° 21′	89° 38′
M : P	010 : 001 =	90 14	89 45
M : P	010 : 001 =	90 19	89 41
Mean	010 : 001 =	90° 18′	89° 41′ 20″

The variation in the angle is due to the M (010) face which does not give a sharp reflection and appears to be made up of innumerable fine twinning lamellæ. The character of sections

Sections of microcline showing cleavage, arrangement of inclusions and angles of extinction. (× 500).

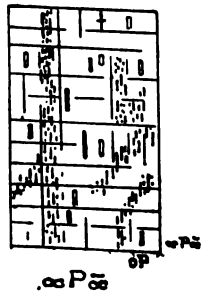

Fig. 12.
Section parallel to the macropinacoid (100).

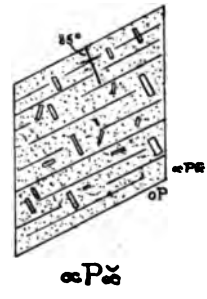

Fig. 13.
Section parallel to the brachypinacoid (010).

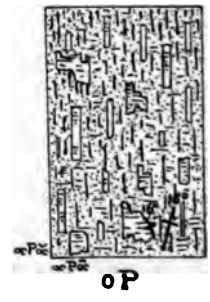

Fig. 14.
Section parallel to the base (001).

parallel to the different faces or axes of the crystal may be better understood from a consideration of the accompanying diagrams (Figs. 12, 13 and 14) than from a description. The

small, approximately rectangular inclusions appear to be sections of minute ægirite crystals. In some cases these are surrounded by minute dots and lines some of which represent cavities, while others are opaque and appear to be magnetite.

In the section parallel to $\infty P\bar{\infty}$ (100) (Fig. 12) the extinction is only slightly inclined to the vertical axis and with very high powers a fine twinning lamellation is observed. Cleavage parallel $\infty P\breve{\infty}$ (010) and $0P$ (001).

In the section parallel $\infty P\breve{\infty}$ (010) (Fig. 13) inclusions of ægirite are seen and the cleavage-cracks are parallel to $0P$ (001). The acute bisectrix makes an angle of 5° with the basal cleavage-cracks and lies in the obtuse angle β.

In the section parallel to $0P$(001), (Fig. 14) the whole surface is seen to be made up of irregular patches which are extinguished respectively at 16° on each side of their line of contact. This section has more the appearance of the microperthitic intergrowths of orthoclase and albite than of microcline but from other considerations, viz., the angle of extinction of the lamellæ twinned according to the albite law and the want of sodium or lime in the crystal as shown by a qualitative test, it is probable that it is microcline and similar to the crystal analyzed by Pisani.

The section parallel $\infty P\bar{\infty}$ (100) when examined in convergent polarized light shows that the acute bisectrix is not at right angles to the section and that the rings about the two optic axes are eccentrically situated in the microscope field. The axes are, however, so wide apart that the size of the angle cannot be measured without the use of an oil bath and an axis-angle apparatus. The optic axes lie in a plain which is approximately perpendicular to the brachypinacoid (010).

Eleolite requires no special description as it is identical in all respects with that found in the eleolite mica syenite (p. 209).

Eudialyte was identified in 1861 by Professor C. U. Shepard* who discovered small nodules of a brilliant crimson mineral in the feldspar of the eleolite rock of Magnet Cove, Arkansas. He at first supposed this mineral to be corundum, but after testing its

* Am. Jour. Sci. Series 2, Vol. XXXVII., 1861, p. 405.

hardness (which he found to be less than 6), and observing that it gelatinized with hydrochloric acid, he decided that it was eudialyte. From that time the occurrence of this mineral in Arkansas has been mentioned in most text books of mineralogy on Professor Shepard's authority, but not until very lately has the subject been revived.

Hidden and Mackintosh have recently published a note* in which they describe this nodular, rose-red, nearly transparent mineral and state that it is probably eudialyte and identical with that discovered by Shepard.

The writer was able, with the assistance of Wm. J. Kimzey of Magnet Cove, to obtain some very good specimens of this rare mineral, several of which were well adapted for crystallographic measurement. Through the kindness of Messrs. W. E. Hidden of New York and C. S. Bement of Philadelphia, he was enabled to measure two other crystals from this locality which were especially interesting. The results of these investigations were first published in a paper entitled, "Eudialyte from Magnet Cove, Arkansas." †

The crystals from this region range from 3 to 18mm in diameter and are, for the most part, thick tabular parallel to the base. They are transparent to semi-transparent and in color vary from rose-red to deep crimson. Cleavage parallel to base is indistinct, and the crystals appear to be traversed by irregular cracks in all directions. The cleavage parallel to $\frac{1}{2}R(10\bar{1}4)$ and $R(10\bar{1}1)$, as noted in the Greenland eudialyte, has disappeared almost entirely from these crystals. The surface of the crystal is in some cases covered by a yellowish coating of altered material; this, however does not appear to diminish its brilliancy, but when it occurs on the base increases the lustre to mother-of-pearl.

The crystals may be divided according to their form into two classes: first, those in which the negative rhombohedrons predominate, and second, those in which the positive ones are the larger. In general, the crystals are terminated above and below by hexagonal basal planes, but these occasionally become

* Am. Jour. Sci., Series 3, Vol., XXXVIII., 1889, p. 494.

† Am. Jour. Sci., Series 3, Vol. XL., 1890, p. 458.

triangular or disappear entirely. The most satisfactory crystal for the measurement of angles was one of only about 3mm in its greatest diameter and of about half that thickness. This crystal belongs to that group in which the negative rhombohedrons predominate and is shown in fig. 15. The measurements from this, combined with those from several other crystals, are given below, and after each measured angle the extreme variation from the mean is appended.

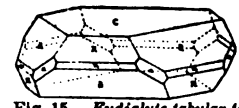

Fig. 15.—*Eudialyte tabular to the base.*

The axial ratio, as calculated from measurements, made on three very good crystals, of the angle between the base and the largest rhombohedron, $-\frac{1}{2}R$, is found to be $a:c=1:2.1174$. As this is deduced from a mean of not less than ten angles, none of which varied more than 25 seconds from the mean angle, 50° 43′ 6″, it is evident that it cannot be far out of the way for the Arkansas variety of eudialyte. Brögger (Syenitpegmatitgänge, p. 498), considers the latest measurements of von Kokscharow† the most correct for eudialyte. Von Kokscharow gives $a : c=1 : 2.1129$ which differs but little from the ordinarily accepted figures, $a : c=1 : 2.1117$, while the value for the Arkansas variety is considerably larger.

The following faces have been observed and measured:—

$c=0R(0001)$, $a=\infty P2(11\bar{2}0)$, $R=+R(10\bar{1}1)$,
$d=-\frac{1}{2}R(01\bar{1}2)$, $n=-2R(02\bar{2}1)$.

Faces.	Mean Angle.	Calculated.	Variation.	Von Koksch Calculated.
$c : d$, (0001) : (01$\bar{1}$2)	50° 43′ 6″	50° 43′ 6″	0′ 24″	50° 38′
$c : R$,(0001) : (10$\bar{1}$1)	67 53 48	67 45 24	3 12	67 42
$c : n$, (0001) : (02$\bar{2}$1)	78 25	78 26 35	10 30	78 25
$c : a$, (0001) : (11$\bar{2}$0)	89 56†	90 0	0 15	90 0
$d : a$, (10$\bar{1}$2) : (11$\bar{2}$0)	47 49 30	47 54 29	4 30	47 58
$d : d$, (10$\bar{1}$2) : (10$\bar{1}$2)	84 21	84 11 2	1 reading	84 4

The variation of these angles and of the axial ratio from those of von Kokscharow would suggest some corresponding variation in the chemical composition.

* Von Kokscharow, Verhandl. der kais. russ. min. Gesellschaft zu St. Petersburg, II., XIV., 1879, p. 205.

† Brögger, loc cit., measured this angle on Norwegian eucolite as 89° 58′ 30″.

An excellent example of that class of crystals in which the positive rhombohedrons predominate is found in a small specimen —not more than 4mm in its greatest diameter—loaned the writer by Mr. C. S. Bement. This is shown in fig. 16. In this crystal one face, $+R$ $(10\bar{1}1)$, is so over-developed that all the rest of the faces seem dwarfed by it. At the first glance, and in fact until the crystal is carefully measured, this large face would be mistaken for the base and the fact that opposite to it the crystal is terminated by a six-sided pyramid would seem to support this view. The crystal is, in reality, to be placed as shown in the cut and the faces which make up the front of the crystal are designated by the same letters as in the preceding figure. The faces forming the back are for the most part composed of known forms in oscillatory combination. Besides these well known faces a large number of new ones appear, of which, however, only a few are large and sharp enough to be worthy of special mention. The most important of these forms are as follows:—

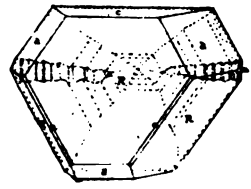

Fig. 16—*Eudialyte tabular parallel to a rhombohedron face.*

$$-\tfrac{3}{11}R(0.3.3.11),\ \tfrac{1}{4}R(10\bar{1}4),\ \tfrac{1}{5}R(10\bar{1}5) \text{ and } -\tfrac{3}{4}R5\ (23\bar{6}3).$$

The angles, measured as nearly as possible, were as follows:

$0R$: $-\frac{3}{11}R$, (0001):(0.3.$\bar{3}$.11)	33° 54′	33° 41′ 52″
$0R$: $\frac{1}{4}R$, (0001):(10$\bar{1}$4)	31 54 ($\pm$30′)	31 26 12
$0R$: $\frac{1}{5}R$, (0001):(10$\bar{1}$5)	25 59 33″	36 3 35

The faces at the back of the crystal lying in the vertical zone and beginning at the top are: $0R$, 0001; $-\frac{3}{11}R$, $\bar{3}$.0.3.11; $-\frac{1}{2}R$ $\bar{1}$012 (large); $-\frac{1}{m}R$, $\bar{1}01m$; (point at back); $\frac{1}{n}R$, $\bar{1}01\bar{n}$; $\frac{1}{4}R$, $\bar{1}01\bar{4}$ (large but dull); $\frac{1}{5}R$, $\bar{1}01\bar{5}$ and $0R$, 000$\bar{1}$ (bottom).

The right and left inclined zones at the back are made up of the following faces; R, 0$\bar{1}$11 and $\bar{1}$101; the prisms $\infty P2$, $\bar{1}\bar{1}20$ and $\bar{2}$110; (point at back); $-\frac{1}{2}R$, 1$\bar{1}0\bar{2}$ and 0$\bar{1}\bar{1}2$. The small zones lying back of a ($\infty P2$, $\bar{1}$210 and 1$\bar{2}$10) are made up of a recurrence of the prisms with the scalenohedrons $-\frac{3}{4}R5$, $\bar{2}36\bar{3}$ and $\bar{6}3\bar{2}\bar{3}$ (determinable only through zone relations).

In order to make sure that the crystal was properly placed

and the faces correctly determined it was imbedded in a short piece of glass tubing just large enough to hold it and which was filled with Canada balsam. This was then placed on an object glass and a thin glass cover placed over it.* The outside of the glass tube was covered with black paint, in order to cut off any side reflections and the preparation was then examined under the polariscope. Owing to the thickness and irregularity of the crystal, the black cross was not very plain, but it was evident on revolving the stage of the polariscope that there was no extinction such as was observed when the crystal was placed in any other position.

The specific gravity is comparatively low and lies between 2.804 and 2.833 at 15° C. These values were obtained from those crystals which were measured, and the lowest was that of the crystal figured in fig. 16. The determination was made by means of a cadmium-borotungstate solution, in which the crystals were placed and which was then brought to such a density that the mineral remained suspended, neither rising nor sinking. The specific gravity of the solution was then determined by means of a 12cc pycnometer.

Thin sections, cut at right angles to the vertical axis, show in parallel light a pink color, and between crossed nicols remain perfectly dark during a complete revolution of the stage. In convergent polarized light such sections show a wide black cross which sometimes opens a little owing to slight optic anomalies, but no colored rings appear. Both the double refraction and the index of refraction are weak. The index is lower than that of Canada balsam and the surface of the section appears smooth. The character of the double refraction is *positive*. By sinking the polarizer and the converging lens the irregular cleavage, which lies approximately parallel to $\frac{1}{4}R$ $(10\bar{1}4)$, becomes visible.

The mineral is comparatively free from inclusions for a crystal which was formed as late in the period of solidification of the rock as this. Magnetite and ægirite or acmite are the only

*Since making this experiment the writer has received Professor C. Klein's exhaustive paper on this method of examining crystals without cutting them. Sitzungsber. d. k. Akad., Berlin, XVIII, 1890, p. 347.

inclusions which have been observed. It appears as if sometimes eudialyte and sometimes microcline was formed first, for first one and then the other is found in idiomorphic crystals. On the whole the eudialyte appears to be the earlier of the two. Decomposition takes place very rapidly and the earlier stages of it are marked by the formation of a yellowish brown mineral with negative double refraction which has been proved to be eucolite.

Since the above article was published by the writer an article by Dr. F. A. Genth on the same subject has been contributed to the American Journal.* Genth's paper was virtually completed before that of the writer came into his hands and hence the close agreement of the angles found is especially interesting since they were measured independently. Pirsson gives the accompanying figure (Fig. 17) and enumerates the following faces: c=0R (0001); r=+R (10$\bar{1}$1); e=$-\frac{1}{2}R$ (01$\bar{1}$2) and a=$\infty P2$ (11$\bar{2}$0.)

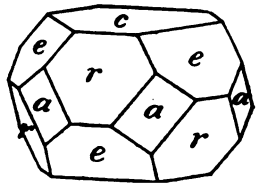

Fig. 17. *Eudialyte from Magnet Cove (after Pirsson).*

The following angles were measured on a crystal 2.5mm in diameter:—

	Pirsson.	*Williams.*	
		Calculated.	*Measured.*
c : r, (0001) : (10$\bar{1}$1)	– 67° 35′ (mean of 5 meas.)	67° 45½′	67° 54′
c : e, (0001) : (01$\bar{1}$2)	– 50 44 (mean of 6 meas.)	50 43	50 43

The specific gravity was determined by Genth to be 2.810.

Genth gives two very valuable analyses of the pink nodular material which he states consisted of material of various shades of color, but appeared to be free from impurities. The analyses are as follows:—

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* Contributions to Mineralogy, No. 50: by F. A. Genth with crystallographic notes by S. L. Penfield and L. V. Pirsson. Am. Jour. Sci. Series 3, Vol. XLI, 1891, p. 397.

In preparing this paper Genth took the charge of the chemical portion while Pirsson measured the crystals and calculated the angles. For this reason the work on the chemical and crystallographic portions of the paper has been in each case referred to the man who undertook it.

Analyses of eudialyte (Genth).

CONSTITUENTS.	a.	b.
SiO_2	51.83	51.68
ZrO_2	11.45	11.62
Ta_2O_5 (?)	0.39	0.29
FeO	4.37	4.35
MnO	0.37	0.30
CaO	14.77	15.05
MgO	0.11	0.07
K_2O	0 48	.....
Na_2O	13.29	.....
Cl	1.42	1.41
Ignition	1.88	1.84
Total	100.31	.....

Genth states that the mineral occurs associated with ægirite, astrophyllite, titanite and zeolites. He suggests the possibility that the variation in color is due to the beginning of alteration.

Astrophyllite occurs sparingly in this rock but in comparatively large (5–10mm) poorly developed crystals. The writer has seen only one specimen of the rock in which this mineral occurs. This specimen was given to him and his attention called to the astrophyllite in it by Dr. Genth, who had already mentioned the mineral in his description of the eudialyte found in the same rock (see above).

The astrophyllite crystallizes in thin, brittle plates which are crowded together in an irregular mass. They are of a brownish yellow color and show an extremely brilliant lustre upon the base (001). The cleavage parallel to the base (001) is also highly perfect. The plates of which this material is composed are combined in such a way that they present a curved structure although in reality each of the individual flakes is flat.

In convergent polarized light a plate parallel to the base (001) shows that the acute bisectrix is perpendicular to it and that the optic axis angle is too wide to allow the optic axes to appear in the field.

A blowpipe examination of a few flakes of this mineral showed the presence of titanium,* manganese and sodium.

Ægirite occurs in gigantic crystals in certain parts of this rock and while it is very common throughout the mass, in the ordinary forms, the large crystals occurring in coarse grained veins or dikes deserve a more special mention.

This mineral was probably noticed long before it was recognized as ægirite, for in the earliest account of the region by Joseph Macrery † black schorl is mentioned as occurring in rectangular crystals which cover a white or reddish feldspar and it is probable that the brilliant, black, nearly rectangular prisms of ægirite were mistaken for schorl, or tourmaline as it is now called.

Featherstonhaugh in his report ‡ mentions hornblende as being a constituent of the coarse-grained syenite and also of the "greenstone." It is probable that in this case he mistook ægirite for hornblende.

It is not at all surprising that these mistakes were made for it was not until the year 1834 that Esmark discovered this mineral near Brevig, Norway, and named it ægirite after the Norwegian god of the sea, Ægir. || The very similar mineral, acmite, which is hardly distinguishable from ægirite, was, however, first discovered in 1784 by H. Ström, who called it "Krystallisirter Hornstein (crystallized hornstone) oder schorl," § and in 1821 P. Ström¶ made it a separate mineral under the name "Werneria" and Berzelius in the same publication gave the name *akmit* or *acmite* from the Greek word for a spear-point.

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* The test in a bead of microcosmic salt with ferrous sulphate was made but gave unsatisfactory results. The wet method with sodium fluoride, sodium pyrosulphate and hydrogen peroxide (Detection and Estimation of Titanium, W. A. Noyes, Journal of Anal. and Applied Chemistry, Vol. V., 1891, p. 39) was then tried and a decided reaction for titanium was obtained with an extremely small quantity of material.

† New York Medical Repository, Vol. III., 1806, p. 48.

‡ Geological Report of the Elevated Country between the Missouri and Red Rivers, etc. 1834, p. 62.

|| Esmark und Berzelius, Neues Jabrbuch. f. Min. 1835, p. 184. Cited after Brögger, (Syenitpegmatitgänge p. 295).

§ H. Ström, Beskrive'se over Eger-Praestegjöld, Kjöbenhavn, 1784, p. 50. Cited after Brögger, p. 295.

¶ P. Ström, Sv. Vet. Acad. Handl., 1821, p. 161. Cited after Brögger, p. 295.

In 1864 C. U. Shepard * mentioned that ægirite (ægirine) was found loose in the soil of Magnet Cove and in association with eudialyte and other minerals. Since that time it has been one of the best known of the minerals brought from that interesting locality.

The ægirite crystals are often 30cm (1 foot) and more in length with a thickness of 3cm (1¼ in.). They form long, almost jet black prisms which show a slight inclination toward green in incident light and which are of a decided green color when seen by transmitted light. There is, however, a slight tendency towards brownish green in some of the specimens which are superficially weathered. From these characteristics it is probable that this mineral is ægirite and not acmite.† The long prisms are often terminated by long steep pyramids whose crystal faces are not at all sharp. They are generally much rounded and do not allow of accurate measurement or determination of their indices. A thin section of one of these large crystals cut parallel to the clinopinacoid (010) gave an extinction angle 3° and showed that the pleochroism was $a > c$.

Many attempts have been made to prepare a section at right angles to the prism faces but without success. The cleavage parallel to the prism was too perfect to allow of much abrasion at right angles to its direction.

An analysis of one of these large crystals was made in 1875 by J. Lawrence Smith‡ as shown below, and in order to compare it with those from Norway the two typical analyses of ægirite and acmite given by Brögger, and one by F. Pisani are appended.

The resemblance between analyses I. and II. is remarkable, but as there is hardly any constitutional difference between ægirite and acmite this similarity does not signify much.

Besides these very large specimens there are crystals of all sizes down to the very minute needle-like forms found included in the microcline, eudialyte etc.

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* Am. Jour. Sci., Series 2, Vol. XXXVII., 1864, p. 407.

† See Brögger (Syenit-gemattgänge, p. 336)

‡ Analysis of Ægirite from Hot Springs, Ark., by J. Lawrence Smith, Am. Jour. Sci., Series 3, Vol. X., 1875, p. 60.

Analyses of ægirite and acmite.

Constituents.	I. Ægirite, Arkansas.	II. Ægirite, Brevig, Norway.	III. Ægirite, Barkevig, Norway.	IV. Acmite, Rundemyr, Norway.
SiO_2	51.41	52.11	51.74	51.35
TiO_2	0.13	.....	.....	.....
Al_2O_3	1.82	2.47	0.47 (*)	1.59
Fe_2O_3	23.30	22.80	26.17	32.11 (†)
FeO	9.45	8.40	3.48	2.59
CaO	2.08	2.60	5.07	Trace.
MgO	0.31	0.41	1.79	.....
MnO	.....	.....	0.46	0.37
Na_2O	11.88	12.10	11.02	11.39
K_2O	Trace.	.....	0.34	Trace.
H_2O	.....	0 30	.....	.....
Total	100.33	101.19	100.54	99.40
Specific gravity	3.53	.....	.....	.....

I. Ægirite from Magnet Cove, analyzed by J. Lawrence Smith. (Am. Jour. Sci., Ser. 3, Vol. X., 1875, p. 60).

II. Ægirite from Norway (Brevig), analyzed by F. Pisani. (Sur l'astrophyllite et l'ægrine de Brevig en Norwége. Note de M. F. Pisani. Comptes Rendus, LVI., 1863, p. 846).

III. Ægirite from Norway (Barkevig, etc.) analyzed by C. Dölter. (Tscherm. Min. Mitth., 1878, p. 372. Cited after Syenitpegmatitgänge, p. 297).

IV. Acmite from Norway (Rundemyr), analyzed by C. Dölter. (Ibid.).

In thin sections the ægirite crystals are seen to be always idiomorphically bounded as regards the other minerals of the rock but they are often grouped together into thick nests made up only of ægirite in such a way that the free crystallization of the individuals has been very much hindered by each other. In no case, however, has a twin crystal of ægirite been found and since Brögger states that twins are especially characteristic of acmite this fact increases the probability that the latter mineral is very rare if not entirely wanting.

* Brögger writes Al_2O_3—0.37 instead of Al_2O_3—0.47. (See Rammelsberg Mineralchemie Ergänzungsheft, p. 24).

† Brögger writes Fe_2O_3—31.11 instead of Fe_2O_3—32.11. (See Rammelsberg, Mineralchemie, Ergänzungsheft, p. 23).

Garnet occurs in precisely the same form and color as in the case of that already described in the eleolite mica syenite (p. 212) and needs no further mention. It is not very common in this rock and seldom appears in idiomorphic crystals.

Wollastonite has been observed in a few cases only.

Titanite appears in idiomorphic crystals (1 to 5mm) which are often of a sulphur-yellow color and form a very striking constituent of the rock. In other cases they have a more decided bronze color and are not so brilliant.

The titanite of this rock also forms prisms elongated parallel to the vertical axis (Fig. 18). These occur both imbedded and virtually free, extending into cavities in the rock and attached only at the lower end of the vertical axis. F. A. Genth has lately analyzed them and in connection with L. V. Pirsson has published the paper already cited. *

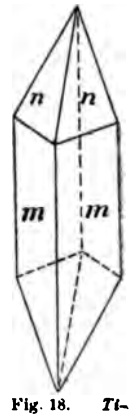


Fig. 18. *Titanite from Magnet Cove (after Pirsson).*

Genth describes the occurrence of the titanite as follows: "It occurs associated with ægirite, orthoclase (or microcline) eleolite, one or two zeolites, eudialyte, and others in small pale yellowish brown or brown crystals. Specific gravity 3.457.

"The crystals are very simple and show a combination of the two forms $m=\infty P(110)$: and $n=-P(111)$†. The faces gave very poor reflections so that only approximate measurements could be made."

An analysis of this material gave Genth the following figures:—

Analysis of titanite. (*Genth.*)

SiO_2	30.84
TiO_2	39.35
FeO	0.73
CaO	28.26
MgO	Trace.
Ignition	0.57
Total	99.75

* Contributions to Mineralogy, No. 50, etc., Am. Jour. Sci., Series 3, Vol. XLI., 1891, p. 394.

† Pirsson's symbols have been changed so as to correspond with those in this report.

Similar elongated crystals, observed by the writer, when slightly weathered are covered with a crust of a white substance the character of which has not been determined.

Magnetite, ilmenite and *pyrite* all occur in considerable quantities but present no peculiarities worthy of special mention.

Decomposition products.—Among the decomposition products of this rock there are several minerals which are especially interesting on account of their comparative rarity. For this reason, therefore, these will receive more than a passing mention.

Natrolite occurs in thick prisms (1 to 2cm or more in diameter) and often forms large masses in this rock. It is pure white and has a distinct cleavage parallel to the prism faces (110) and a glassy lustre. Although the crystallization has usually been so hindered that the crystal faces seldom appear, in a few cases beautifully terminated crystals have been observed extending into the the small cavities left between the crystals. One small crystal (Fig. 19) of this sort which had a length of 4mm and a diameter of 2mm showing the following faces: ∞P (110), $\infty P\bar{\infty}$ (100), $\infty P\breve{\infty}$ (010) and P (111). One of the pyramid faces (111) shows a striation parallel to a polar edge lying in the brachydiagonal section but with that exception all the faces are sharp and smooth.

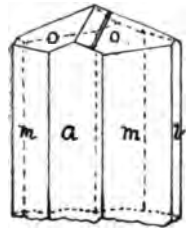


Fig. 19. *Natrolite from Magnet Cove.*

A qualitative examination of some of this material showed flocculent silica, when the mineral was treated with hydrochloric acid and the solution gave a large precipitate of alumina with ammonia. Lime and magnesia were entirely wanting, but the flame reaction gave a strong reaction for sodium and very slight traces of potassium.

Through the kindness of Dr. F. A. Genth the writer is enabled to publish the following analysis of this mineral. The analysis has never previously been published but Dr. Genth has generously placed it at the disposal of the Survey:—

Analysis of natrolite. (*Genth*).

SiO_2	47.97
Al_2O_3	26.51

Na_2O	15.98
Ignition	9.81
Total	100.27
Specific gravity	2.243

Dr. Genth states that this is "the beautiful natrolite with the large cleavage-planes" and, as is evident from the analysis, it is very pure.

Whole crystals and sections of the same show a perfectly orientated extinction in parallel polarized light and in convergent light the optic axis plane is seen to lie in the brachypinacoid section (010.) The angle of the optic axes is near 90° and the acute bisectrix is coincident with the vertical axis, therefore in plates parallel to the cleavage the axes are invisible in the air.

Thomsonite (*Ozarkite*) also occurs in small quantities in this rock but needs no special description.

Brucite occurs in white, transparent or semi-transparent, regular, hexagonal plates which are generally about 2mm in diameter but may be found very much smaller. They present a laminated surface and show a very decided cleavage parallel to the base. The faces which have been observed are $0P$ (0001), $2R$ (20$\bar{2}$1) and $-4R$ (04$\bar{4}$1.) The angles were not measured, but it is evident from the appearance of the crystal that the faces enumerated are those which exist.

In parallel polarized light a plate parallel to the base (0001) becomes a dark gray, but shows variations of intensity in different parts of the plate. These variations are emphasized by the use of a selenite plate. In convergent polarized light a black cross is observed which opens slightly when the stage is revolved. The size of the optic angle in different parts of the plate is very variable and the position of the plane of the optic axes varies from one point to another. By means of a quarter-undulation mica plate the character of the double refraction is determined to be positive.

*Manganopectolite** was first described by the writer and occurs as thick tabular crystals varying very much in size, the

* Manganopektolith, ein neues pektolith-ähnliches Mineral von Magnet Cove, Arkansas, von J. Francis Williams. Zeit. für Kryst. and Mineral. Band XVIII. 1890, p. 386.

largest being about 10cm in length. The best specimen of this rare mineral which has been found was a thick crystal about 20×10×6mm in size. It was broken through the center parallel to the broader face. In the interior the crystal was perfectly transparent and of a grayish color, but was incrusted with an opaque, brown deposit of weathered material.

The following faces were observed and measured:—

$0P$ (001), $\infty P\bar{\infty}$ (100), $+2P\bar{\infty}$ (201), $\infty P\check{\infty}$ (010).

	Measured.	Calculated.
(001) : (100) —	84° 42′	84° 42′
(001) : (201) —	44 26	44 25
(100) : (401) —	50 55	50 53

β = 84° 42′ and the axis ratio when b and c are made to correspond with those of wollastonite is $a : b : c = 1.0534 : 1 : 0.4840$. It is evident that a better ratio could be obtained from a crystal having faces other than those in the orthodiagonal zone.

The cleavage parallel to $0P$ (001) is very perfect while that parallel to $\infty P\bar{\infty}$ (100) is hardly inferior to it. The lustre on the former is mother-of-pearl and on the latter silky.

Hardness..... ..... 5.

Specific gravity..... 2.845

A chemical analysis by the writer gave as the mean of three determinations the following composition:—

Analysis of manganopectolite.

CONSTITUENTS.	Mean.	Greatest variation from mean.
SiO_2	53.03	0.18
Fe_2O_3	0.10	
Al_2O_3		
CaO	30.28	0.40
MgO		
MnO	4.25	0.10
Na_2O	8.99	0.06
H_2O	2.43	
CO_2	0.82	
Total	99.90	

From a thin section of this mineral it was evident that it contained small particles of calcite scattered through it. It seems, therefore, perfectly proper to consider all the carbon dioxide as belonging to that mineral and to deduct it in the form of $CaCO_3$ from the analysis and to recalculate the latter to one hundred per cent.

By comparing this corrected analysis with that of pectolite it is evident that manganopectolite is simply a form of pectolite in which a portion of the calcium is replaced by manganese. By calculation it may be shown that when one-tenth of the calcium is thus replaced a composition is obtained which corresponds very closely to that arrived at by analysis.

For comparison the composition as calculated from the formula $(\frac{9}{10}Ca, \frac{1}{10}Mn)_2 NaH Si_3O_9$, and the theoretical composition of pectolite ($Ca_2NaH Si_3O_9$), are placed by the side of the "corrected" analysis.

Comparison of manganopectolite with pectolite.

CONSTITUENTS.	Corrected analysis.	Calculated $(0.9CaO, 0.1Mn)_2 NaH Si_3O_9$	Pectolité $Ca_2NaH Si_3O_9$
SiO_2	54.10	53.75	54.22
Fe_2O_3	0.10	.....	.....
CaO	29.82	30.08	33.74
MnO	4.34	4.23	.....
Na_2O	9.16	9.25	9.33
H_2O	2.48	2.69	2.71
Total	100.00	100.00	100.00
$CaCO_3$	1.87	Sp. Gr. { 2.74 10. 2.88	
Spec. Gravity	2.845		

It is evident that the material used in this analysis was very pure from the fact that neither magnesia nor alumina were present in weighable quantities and that the ferric oxide only amounted to 0.10 per cent.

The optic properties of this mineral show its close connection with pectolite fully as completely as does the chemical

analysis. A section parallel to the more perfect cleavage (001) showed parallel extinction and in oil in convergent light the rings about the optic axes were visible but did not allow of the measurement of the axial angle about the obtuse bisectrix. The figure was perfectly centered, showing that the bisectrix stood perpendicular to the base (001). The plane of the optic axes was at right angles to the symmetry-plane of the crystal.

Much difficulty was experienced in obtaining a section parallel to the plane of symmetry, that is, perpendicular to the acute bisectrix, on account of the perfect cleavage parallel to the base (001) and orthopinacoid (100). After many trials a section was secured which was near enough to the required direction to enable the axial angle to be determined as approximately 15° for sodium light. The double refraction is very strong and its character is positive. The dispersion of the red rays is greater than that of the blue, $\rho > \upsilon$, and is so strong that the interference figure resembles that of titanite. Owing to the strong dispersion of the axes that of the acute bisectrix is not apparent.

In thin sections parallel to the base small interpositions of calcite appear which are usually situated with their principal axes vertical and give very perfect uniaxial figures. The formation of these interpositions was probably nearly contemporaneous with that of the manganopectolite itself, for in some cases they appear idiomorphic and in others they occur as irregular grains. Other inclusions are entirely wanting.

The crystals weather in such a way that a brown coating of manganese oxide is formed which is completely opaque. In some cases this oxide of manganese has completely replaced the manganopectolite.

Like pectolite, this mineral must be considered as a zeolite for on being heated to a 115° C. it gives off only 0.25 per cent of water. When the temperature is raised to a low red heat 1.15 per cent additional water is lost and finally at bright red heat it becomes anhydrous. It is probable that some of the 1.15 per cent lost at a low red heat is the 0.82 per cent carbonic acid which the mineral contains. Manganopectolite dissolves slowly

in concentrated hydrochloric acid leaving finely divided silica behind. It melts to a glass only at a very high heat. The spectroscope shows the presence of lime and sodium and a small portion of the mineral fused with sodic carbonate gives the characteristic bluish green color of manganese.

Eucolite.—According to Brögger (Syenitpegmatitgänge, p. 489) all those crystals which have the form of eudialyte and essentially its chemical composition, but *negative* double refraction in place of *positive*, are to be considered *eucolite*. It appears, therefore, that the yellowish brown crystals bearing a great resemblance in form and size to eudialyte, but which are characterized by their negative double refraction, are to be classed under this head. The crystals which appear in the Arkansas rock are of a much lighter brown or brownish yellow color than those from Norway. The cleavage parallel to the base (0001) is much more pronounced than in eudialyte, but in other directions it is about equally poor with that already noted.

The following faces have been observed (fig. 20): $c=0R$ (0001), $R=+R$ (10$\bar{1}$1), $d=-\frac{1}{2}R$ (01$\bar{1}$2), $g=\infty P$ (10$\bar{1}$0), $a=\infty P2$ (10$\bar{2}$0). Some of the angles between these faces and the base have been measured, but the poor reflections prevent the obtaining of accurate results. The angles recorded are probably not nearer than from 15′ to 30′ to the true angles. Owing to these large limits of error, it is impossible to calculate any axial ratio for this mineral, but the angles as measured do not differ very much from the corresponding angles of eudialyte.

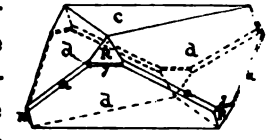


Fig. 20. *Eucolite from Magnet Cove.*

Angle.	Measured.	Calculated.
$c : d$ (0001) : (01$\bar{1}\bar{2}$)	50° 40′ 30″	50° 43′ 6″
$c : R$ (0001) : (10$\bar{1}$1)	67 12	67 45 24
$c : a$ (0901) : (1120)	89 53	90
$c : g$ (0001) : (10$\bar{1}$0)	90 25	90

The specific gravity taken in the same way as that of eudialyte gave 2.6244 to 2.6630 at 15° C. This is extremely low, but even after bringing in a correction for adhering ortho-

clase (sp. gr.=2.55—2.62) the figures would not be much higher.

Hardness 5 to 5.5.

In thin sections this mineral appears semi-transparent, and is of a white to a very light yellow color. In convergent polarized light a section perpendicular to the principal axis shows a black cross which when tested with a mica plate establishes the negative character of the double refraction very plainly. Magnetite and ægirite appear to be only inclusions. Some crystals were found which were made up of both pink and yellowish brown material, and in these cases it was always found that the former was positive and the latter negative.

Wilhelm Ramsay in his "Geologische Beobachtungen auf den Halbinsel Kola"* has observed that, in the eudialyte of the nepheline syenite which he describes, both positive and negative as well as isotropic zones appear, but that no difference in color nor in the indices of refraction between the various parts was detectable. Ramsay's observations were made by means of a selenite plate on sections, which were slightly inclined to the principal axis, while those on the Arkansas mineral were made by means of a quarter-undulation mica plate on sections parallel to the base.

From the low specific gravity and hardness, as well as the want of complete transparency in the eucolite crystals, it is almost certain that these crystals are decomposed or weathered eudialyte. To these facts may be added the observations that, in cases where the eudialyte has begun to weather, it is found in the form of pink grains surrounded by a soft, yellowish brown powder, which resembles very closely the eucolite just described. Moreover, it is probable that the yellowish coatings observed on the surface of the eudialyte crystals already described are made up of this same brownish yellow mineral. A determination of the amount of water in a specimen of the eucolite would be of use in deciding the question of its origin.

3. Eleolite Porphyry.

Eleolite Porphyry is characterized, according to the division

* Fennia, Bulletin de la Société de Géographie de Finland, Tome III., No. 7, pages 42 and 43.

of rocks adopted * in this report, by the occurrence of phenocrysts of eleolite imbedded in a fine-grained to aphanitic groundmass, consisting of eleolite, ægirite, etc., and by the absence of feldspar among the phenocrysts. In cases where the feldspar predominates the rock is considered to incline towards tinguáite.

Eleolite porphyry occurs at several points in the Cove but in scarcely two of them does it appear in exactly the same form. It sometimes appears as a mass of yellowish or pinkish phenocrysts of eleolite 4 to 5mm in size imbedded in a dark crystalline groundmass. These crystals form at least 50 per cent of the rock. In other cases the eleolite is much less frequent in its occurrence and is then almost always of a beautiful pink color. In such cases as the preceding the groundmass is dark and distinctly crystalline.

Still another variety of this rock occurs in which the eleolite has become very indistinct and the groundmass has lost its crystalline appearance and has become much finer grained. This last variety is very hornstone-like in its characteristics.

a. Coarse-grained Eleolite Porphyry.

When the coarse-grained variety of eleolite porphyry is examined under the microscope the porphyritic structure is very evident. The large phenocrysts of eleolite are imbedded in a groundmass of smaller crystals of the same mineral and of diopside which form a completely holocrystalline, fine-grained base of a greenish color.

Eleolite of the first generation occurs in large hexagonal prisms whose heighth and diameter are about equal. It is of a yellowish or pinkish color and shows the characteristic oily lustre very distinctly.

Under the microscope the eleolite crystals appear in hexagonal or rectangular sections and are easily recognized by their optic properties. They are usually filled with innumerable,

* Rosenbusch states (Mikroscopische Physiographie, Band II., 1887, p. 285) that eleolite porphyry is characterized by phenocrysts of nepheline and alkali feldspar, but in this rock the feldspar has been reduced to a minimum and eleolite or nepheline crystals constitute all the phenocrysts.

small gas inclusions which take the form of minute dots and slender rods. The latter are not more than 0.007mm in length and of about one-tenth that thickness, while the dots are not more than 0.0005mm (one fifty thousandth of an inch) in diameter. These rods and dots are all arranged in lines parallel to the principal axis and are so close together (0.002mm) that without the use of high magnifying powers they give the appearance of a striation parallel to the vertical axis. The smallest of these inclusions appear black owing to the total reflection of light which takes place inside of them. In certain zones inclusions of large size occur and give a banded appearance to the crystals. No liquid inclusions have been detected in either the large or small cavities; mineral inclusions are likewise wanting. Along the cracks of the crystals decomposition has often taken place with the formation of the usual decomposition products.

Eleolite of the second generation is in much smaller crystals than that of the first generation, and it also shows a tendency towards idiomorphism. The crystals have, however, in most cases continued their growth after the formation or the beginning of the formation of the diopside crystals so that although the centers of the crystals are clear and free from inclusions the edges include completely and partially formed crystals of diopside. Inclusions like those in the eleolite of the first generation are found also in those of the second.

Diopside occurs in both idiomorphic and allotriomorphic crystals which appear under the microscope a light yellowish green in the center and a darker green near the outside. They are comparatively small and show distinctly by their form and position that they crystallized after the eleolite of the first generation, but that their formation began before that of the eleolite of the second generation ceased. The cleavage and crystal forms are as usual.

The diopside is very slightly pleochroitic and its angle of extinction is large; it has been measured in some cases, where the crystal form was sufficiently distinct to indicate the position of the vertical axis, and found to be as much as 45° to 50°. No

sensible diminution of this angle was observed near the edge. In many cases twins occur and they always follow the law, twinning and composition plane, the orthopinacoid (100). In some cases the twinning takes place in such a way that there is only a thin plate in the twinned position included between two portions of the principal crystal.

Melanite occurs in small crystals which differ in no way from those already described (p. 212).

Biotite is rare and when present is always of secondary origin.

Titanite is common and appears in comparatively large, idiomorphic crystals of the usual form.

Magnetite is scarce.

The order of succession in which the minerals were formed is as follows: Titanite and magnetite, eleolite of the first generation, diopside, eleolite of the second generation, melanite, biotite, decomposition minerals.

A chemical analysis of this rock made by the Survey, W. A. Noyes, analyst, gave the following percents:—

Analysis of eleolite porphyry.

SiO_2	44.50
TiO_2	1.40
Al_2O_3	22.96
Fe_2O_3 (incl. FeO)	6.84
CaO	8.65
MgO	1.65
K_2O	4.83
Na_2O	6.70
H_2O (loss on ignition)	2.06
Total	99.59

This evidently connects this rock directly with the eleolite syenite of the cove and ridge types and not with the Diamond Jo type.

b. Fine-grained Eleolite Porphyry.

This form of eleolite porphyry is a dense, dark rock with less frequent pink crystals of eleolite and differs from the rock just described in the following points:—

The groundmass contains orthoclase in poorly defined crys-

tals which, together with the secondary eleolite, make up the most of the mass.

Much secondary biotite is found in most of the slides of this variety of rock. It occurs in short, thick plates of a brownish color and shows strong pleochroism. It is scattered more plentifully through the eleolite than through the orthoclase crystals.

In many cases melanite has been observed. It is often almost filled with small eleolite crystals which give it a honeycombed appearance. It also occurs in small, sharp, isotropic crystals.

The crystals of the groundmass already mentioned are intermingled with quantities of minute, green crystals (0.004mm in diameter) which are thick prismatic or irregular in form and are much rounded on the edges. They are often grouped together in such a way as to indicate the previous existence of larger crystals of the same substance. These minute crystals have a large angle of extinction and little or no pleochroism and are probably diopside.

The phenocrysts of eleolite, like those in the preceding rock, are often much decomposed. The most important alteration product is cancrinite.

The hornstone-like variety of this eleolite porphyry is the rock which has already been mentioned (page 177) as the one whose true character is hard to determine even under the microscope. It often presents a bluish gray, hornstone-like appearance and on account of a complete absence of sharp crystals might easily be mistaken for the metamorphosed shale described later. It may perhaps be described by the name eleolite felsite or felsitic eleolite syenite.

Its groundmass consists of an extremely fine-grained, doubly refracting mass whose character cannot be definitely determined and in which are scattered numberless, extremely minute, colorless or slightly greenish crystals which probably represent the small diopside crystals described under the last rock. Larger prismatic crystals of the same mineral also occur. When closely examined macroscopically spots are observed in the rock which have a slightly pinkish color and, although not sharply defined,

have a decidedly different appearance from the rest of the rock. Under the microscope these appear to be still finer grained than the rest of the rock and to be somewhat purer in substance. It is probable that had the rock had more time in which to solidify these spots would have become eleolite crystals. The rock on the whole presents such an appearance that it may well be regarded as merely a more quickly cooled form of the last described rock which, had it solidified more slowly, would have presented the same form as the latter.

A chemical analysis of this rock made by the Survey, W. A Noyes, analyst, shows very distinctly that it belonged to the igneous and not to the metamorphic rocks since, except in the case of a direct contact, it is difficult to conceive of enough alkali being added to a shale to give it the composition shown below. In order that this analysis may be compared with those of some of the shales from the same geologic formation to which the eleolite felsite must be referred if it is of sedimentary origin four analyses of shales made by the Survey, R. N. Brackett, analyst, are placed along with it.

Comparison of analyses of eleolite felsite and certain shales.

CONSTITUENTS.	I. Magnet Cove.	II. Little Rock.	III. Round Mountain	IV. Round Mountain.	V. Fort Smith.
SiO_2	51.35	56.30	57.12	64.04	58.43
TiO_2	0.80	.....	.....	.....	.....
Al_2O_3	20.21	23.39	24.32	21.55	22.50
Fe_2O_3	4.90	9.29	7.69	4.78	8.11
FeS_2	4.01	0.26	0.43	0.26	0.29
CaO	5.75	0.36	0.72	0.59	0.32
MgO	1.53	1.49	1.74	0.96	1.14
K_2O	6.68	1.36	2.07	1.56	2.18
Na_2O	4.43	2.76	0.53	0.80	1.03
H_2O	(?)	5.16	7.58	5.94	6.87
NaCl	0.06	.....	.....	.....	.....
SO_3	0.04	.....	.....	.....	.....
P_2O_5	0.28	.....	.....	.....	.....
Total	100.04	100.37	102.40	100.48	100.87

I. Eleolite Felsite from the "Ridge," 100 yards north of Dr. Thornton's house, Magnet Cove, Ark. Analyzed by W. A. Noyes.

II. Shale from the railway cut at the south end of the upper bridge, Little Rock, Ark. Analyzed by R. N. Brackett.

III. Shale from Round Mountain, 5 N., 10 W., section 6, Ark. Analyzed by R. N. Brackett.

IV. Dark gray shale, Round Mountain, 5 N., 10 W., section 6, Ark. Analyzed by R. N. Brackett.

V. Friable, yellow shale 800 feet south of rifle pits on "Nigger Hill" south of Fort Smith, Ark. Analyzed by R. N. Brackett.

Many other rocks which are apparently similar to this occur (page 196) along the Cove ridge and in every case the question of their origin presents itself. It is probable that in some cases they should be classed with these felsitic rocks, but there are also very many metamorphosed sedimentary rocks among them which it is difficult to distinguish from the felsite without the aid of chemical analyses and microscopic sections. These rocks have been classed under the head of "hornstone" and will be described later among the "contact rocks."

4. Eleolite Tinguáite.

Eleolite tinguáite is characterized by the occurrence of phenocrysts of orthoclase or sanidine imbedded in a groundmass of feldspar, eleolite, etc.* It forms narrow bands crossing "The Ridge" in an east-southeast direction at several points whose locations are described in the preceding chapter. It is of a gray or black color and the white orthoclase phenocrysts stand out sharply from the groundmass. The rock breaks easily and shows a waxy fracture. The only phenocrysts which have been observed are large orthoclase crystals which not uncommonly reach a diameter of 20mm, but vary much in size in the different specimens. They are always thin tabular parallel to the clino-pinacoid (010) and thus resemble sanidine, but they are opaque and of a white color and do not possess the characteristically glassy appearance of sanidine. Under the microscope the rock appears porphyritic and shows a fine-grained, allotriomorphic granular

* Under the head of "Elæolithsyenitporphyre" (Mik. Phys., B. II., 1887, p. 369) Rosenbusch mentions a rock from the Pesmeda Mt., Tyrol, described by Dölter (Jahrb. k. k. Reichsanstalt, Band XXV., 1875, p. 226) in which much the same order of crystallization was observed.

groundmass in which are imbedded the phenocrysts of sanidine and which itself consists of a confused mixture of sanidine, eleolite and secondary mica, with here and there some of the bisilicates.

Orthoclase (*sanidine*) *of the first generation* varies, as has been stated above, between wide limits in point of size, but in all cases it has the same general characteristics. The only faces which have been observed on it are $0P$ (001); $\infty P\infty$ (010); ∞P (110) and $+P\bar{\infty}$ (10$\bar{1}$).

Under the microscope it is usually only semi-transparent and shows the ordinary cleavage-planes and angle of extinction of potash feldspar. In convergent polarized light it shows a very small optic angle which, although it has not been measured, is evidently not over 10 or 15 degrees in ordinary light. The plane of the optic axes in all cases which have been observed, lies parallel to the clinopinacoid. The crystals are very free from all kinds of mineral inclusions but they contain both liquid and gaseous inclusions in small quantities. Twins according to the Carlsbad law are not uncommon although the single crystals predominate.

It is evident from the above mentioned characteristics that the feldspar is sanidine rather than orthoclase.

Orthoclase (*sanidine*) *of the second generation* appears only under the microscope and is invisible to the naked eye. It forms irregularly bounded crystals which are usually filled with inclusions of secondary biotite and dust-like magnetite. It may be recognized as potash feldspar by its characteristic cleavage, extinction and behavior in polarized light. The individual crystals of this mineral which form the groundmass are so massed together that every indication of crystal form is lost where they join each other; where they come in contact with the residual groundmass they are corroded and eaten away until no exterior crystal form remains. They are often 0.5mm in diameter and form a good part of the groundmass, the rest of which consists of smaller crystals of potash feldspar, which are evidently of a still later formation, and which contain even more biotite and other impurities.

Eleolite (*nepheline*) is very scarce. There are a few small

crystals of cancrinite in the groundmass which may have been derived from eleolite and, in a few instances, the undecomposed mineral has been observed surrounded by decomposition products. The undecomposed material gave a uniaxial cross and negative double refraction. The amount of sodium present indicates either that the feldspar is very rich in that element or that some sodium mineral is present in appreciable quantities.

Secondary biotite occurs scattered through the feldspar of the second or third generation in the form of irregular plates of a reddish brown color. It is probably due to the decomposition of some original bisilicate. The plates are usually either very small (0.05mm) or else they are completely honey-combed in their structure and include the light colored silicates within their borders.

Secondary magnetite appears in the form of long rods and in irregular masses which often indicate by their arrangement some decomposed bisilicate.

A chemical analysis of this rock was made by the writer with the following results:—

Analysis of eleolite tingudite.

SiO_2	53.76
TiO_2	none
Al_2O_3	23.21
Fe_2O_3	1.27
FeO	3.18
CaO	2.94
SrO	0.04
MnO	none
MgO	0.23
K_2O	7.01
Na_2O	6.97
Li_2O	trace
Cl	0.02
P_2O_5	trace
Loss on ignition	1.71
Total	100.34

The above analysis shows that the rock is entirely free from titanium and associated elements, but the large amount of alkali

LEUCITE SYENITE DIKE ROCK.

FROM MAGNET COVE, ARK. ⅛ NATURAL SIZE.

Scale: 0 1 2 3 4 5 6 7 8 9 10 Centimeters.
0 1 2 3 4 Inches.

present—nearly 14 per cent—shows its probable association with the syenitic rock.

Taken as a whole the rock is very unsatisfactory from a petrographic point of view. With the exception of the large phenocrysts of orthoclase (sanidine) and in a few instances of the eleolite no crystals appear which are well defined or distinctly characterized. Were it not for the great size of the phenocrysts and of the close correspondence of the chemical analysis with that of the eleolite syenite (Diamond Jo type) and of the leucite syenite dike rocks, the rock would be considered a metamorphosed sedimentary bed, but for the reason just stated it is classed in the group of the tinguáites.

C. Leucitic Dike Rocks.

*1. Leucite Syenite Dike Rock.**

The leucite syenite dike rock as it occurs in the Magnet Cove region is a hypidiomorphic granular combination of pseudoleucite,† eleolite, orthoclase, and basic silicates, which presents a more or less perfect granitic structure and is genetically connected with the eleolite syenite dike rocks.

This exceedingly rare and as yet almost unstudied rock forms a comparatively large mass in Magnet Cove and is directly associated with the eleolite syenite of the Diamond Jo type (p. 233). It is macroscopically distinguished by the large pseudoleucite crystals which are imbedded in a finer grained groundmass and give a very characteristic appearance to the rock. This groundmass consists principally of eleolite, black garnets and feldspar all of which are easily distinguished without the use of a glass. The difference in the size of the pseudoleucite crystals and the other constituents in many cases gives to the whole a somewhat porphyritic appearance although a true

* Rosenbusch (Mik. Phys., Band II., 1887, p. 607) states that it is one of the most striking facts in the whole field of petrography that the mineral leucite, which so far as is known occurs only in the younger eruptive rocks, was not formed until the later periods of the earth's history.

† The term *pseudoleucite* is used to designate that mineral which occurs so plentifully in this rock and which is bounded by crystal faces showing that it was once a leucite crystal, although no particle of the original leucite substance now remains.

porphyritic structure is not observed in typical specimens of this rock.

Microscopically the groundmass in which the pseudoleucites lie is seen to be somewhat porphyritic, in that the eleolite crystals are large and idiomorphically bounded and lie in a hypidiomorphic granular groundmass of melanite, diopside and smaller, idiomorphic eleolite crystals.

Pseudoleucite forms large, icositetrahedral crystals often 5cm in diameter. The larger of these are usually rough on the outside and indicate that they have been strongly acted upon by decomposing agents. They are covered with a light yellow to dark brown coating, but when broken usually show a white interior with small crystals of magnetite and pyroxene disseminated through them. Eleolite is occasionally imbedded in them and forms quite large, idiomorphic individuals. In some cases it has been found lying half in a crystal and half in the matrix. The rough exterior coating of the pseudoleucites is seen either macroscopically or with the aid of a magnifying-glass to be made up of orthoclase (sanidine) crystals which lie with their longer sides parallel to the edges of the deloid faces of the icositetrahedron. On closer examination these long, apparently prismatic crystals are found to be the edges of thin, tabular crystals which lie with their symmetry-planes (010) perpendicular to the icositetrahedral faces (see below).

Under the microscope the pseudoleucites are found to consist of a network of small, allotriomorphically bounded, tabular orthoclase crystals which are generally arranged in radial forms and which are often interspersed with small, allotriomorphic eleolite crystals and idiomorphic pyroxenes.

It is common to find the orthoclase (sanidine) crystals lying with their symmetry-planes at right angles to the edge of the section and hence forming a sort of palisade about the edge. In a medial section from a 5cm crystal this palisade structure was very apparent and inside of it radiate masses of feldspar were found. These radiate masses are so closely bunched together that there is very little intermediate space left and consequently the only conspicuous mineral in the section is orthoclase. Eleo-

lite, or rather its decomposition product, cancrinite, is often noticed in very small grains included between the feldspar crystals. In the fresher specimens it seems to form about one-fourth of the whole mass. In some sections the eleolite becomes quite conspicuous and in some cases even forms large macroscopic crystals.

The orthoclase (sanidine) individuals in the radiate masses of the above mentioned medial section of pseudoleucite when viewed in parallel polarized light are found to extinguish consecutively and thus to have a spheroidal structure. The orthoclase (sanidine) is nearly opaque, white and shows a distinct basal cleavage. It is sometimes twinned according to the Carlsbad law although single individuals are the more common.

The eleolite appears in a few cases as large, yellowish, idiomorphic crystals, but is as a rule only detectable through its decomposition products. These may be etched with hydrochloric acid and stained with fuchsine, but the results obtained are not very satisfactory.

Pyroxene exists in poorly defined, greenish prisms which were at one time idiomorphically bounded but which have since then been entirely altered about the edges into secondary products. From its color and extinction it is probable that it is ægirite. At best it is very scarce and in the fresher crystals is often entirely wanting.

Minute grains of magnetite have been observed.

In order to obtain an idea of the chemical constitution of these most interesting pseudomorphs some of the freshest crystals were selected from the same rock from which the material was obtained for the complete analysis (see later).

The analysis was made by the writer and was divided into two parts as follows: The portions of the crystals which were soluble and insoluble in hydrochloric acid were analyzed separately and a total analysis was afterwards made as a control of the sum of these results. The method of treatment was that used and described at length by Rammelsberg in his analyses of

similar crystals from old Vesuvius lava.*

The results of these partial analyses and the sums of their different components as well as the check total analysis are given below.

Table of analyses of pseudoleucite.

CONSTITUENTS.	ARKANSAS. (Willams.)				MT. VESUVIUS. (Rammelsberg.)			
					Material from Prof. Scacchi.		From Professor Mitscherlich.	
	Soluble part.	Insoluble part	Sum.	Check analysis	Sol.	Insol.	Sol.	Insol.
SiO_2	16.03	(39.03)	(55.06)	55.06	18.39	(39.91)	24.00	(34.78)
Al_2O_3 } Fe_2O_3 }	13.27	11.99	25.26	24.88	12.11	11.69	12.47	11.58
CaO	0.38	0.27	0.60	0.59	0.56	0.40	0.71	.....
SrO	trace	trace	trace	trace	.....	.....	.....	.....
MgO	0.08	0.20	0.28	.....	0.17	.....	.....	.....
K_2O	1.92	8.42	10.34	.....	4.10	6.84	2.86	8.64
Na_2O	6.38	1.22	7.60	.....	5.50	0.30	5.25	trace
Li_2O	trace	trace	trace	.....	.....	.....	.....	.....
H_2O (ignition)	(1.78)	.....	(1.78)	1.78	.....	.....	.....	.....
Total	39.79	61.13	100.92	.....	40.83	59.14	45.29	55.00
By actual weight	38.82	61.18	100.00	.....	Sum=99.97		100.29	

* The finely powdered material was digested on a sand bath for several hours with dilute hydrochloric acid and from time to time concentrated acid, in small quantities, was added until the fluid had attained a concentration of about 1 to 1. The liquid was then diluted, filtered through a quantitative filter, thoroughly washed and the residue, filter and all, was digested for one hour with a strong solution of sodic carbonate in order to remove any silica which was separated by the action of the hydrochloric acid. The liquid was filtered and the treatment with sodic carbonate was repeated and the liquid was then again filtered and was found to contain little or no additional silica. The residue was very thoroughly washed with water and dilute hydrochloric acid to remove all traces of the sodic carbonate and was then dried, ignited and weighed. The sodic carbonate extractions were acidified with hydrochloric acid and evaporated to dryness, heated to 120°C. in an air bath, taken up with a few drops of hydrochloric acid, filtered, dried, ignited before the blast lamp, weighed, treated with hydrofluoric acid and weighed again.

The filtrate from the digestion with hydrochloric acid was evaporated to dryness, weighed as above, and the amount of silica found was added to that from the sodic carbonate treatment and considered as the silica of the soluble portion of the mineral. The filtrate from the silica of the hydrochloric acid digestion was then analyzed for iron, alumina, lime, strontia, magnesia, potash, soda and lithia.

The insoluble portion after being weighed was dissolved in sulphuric and hydrofluoric acids and a determination made of everything except silica which could be estimated only by difference. (Poggendorf's Annalen. Band XCV., p. 142).

In order to compare the analyses of the Arkansas material with those made by Rammelsberg of the two specimens of the similar minerals from the old Vesuvius lavas which were sent him by Professors Scacchi and Mitscherlich these two series of analyses are placed in one table.

The quantities enclosed in parentheses were not directly determined in the columns where they appear, but were either only determined once for all or they were determined as the difference between the sum of all the constituents and one hundred. All the water or loss on ignition in the analyses of the Arkansas material was placed under the soluble part, because, as the insoluble part was heated before the blast lamp previous to analysis, it was impossible to determine its water.

If the results of the partial analyses of the pseudoleucites from Magnet Cove be recalculated to 100 per cent, they are found to approach very closely to the composition of eleolite and orthoclase respectively.

For the sake of comparison analyses of crystals of eleolite and orthoclase are placed with the recalculated partial analyses of the pseudoleucite from Magnet Cove.

Table showing similarity of partial analyses of pseudoleucite to analyses of eleolite and orthoclase.

CONSTITUENTS.	I. Sol. part of pseudoleucite.	II. Eleolite from Magnet Cove.	III. Insol. part of pseudoleucite.	IV. Orthoclase from Brazil.
SiO_2	42.18	44.46	63.84	63.84
Al_2O_3	34.90	30.97	19.61	19.24
Fe_2O_3		2.09		
CaO	0.86	0.66	0.44	0.41
SrO	trace		trace	
MgO	0.21		0.33	
K_2O	5.06	5.91	13.78	12.66
Na_2O	16.79	15.61	2.00	2.48
H_2O	(*)	0.95		0.35
Total	100.00	100.65	100.00	98.98

* The water was omitted from the analysis of this part because there was no certainty that it belonged here and the analysis was brought to 100 per cent without it.

I. Soluble portion of pseudoleucite crystals from Magnet Cove, Ark., recalculated to 100 per cent. (Eleolite.)

II. Eleolite from Magnet Cove, Ark. Analyzed by Smith and Brush. Am. Jour. Sci., Series 2, Vol. XVI., 1853, p. 371. (See page 210).

III. Insoluble portion of pseudoleucite crystal from Magnet Cove, Ark., recalculated to 100 per cent. (Orthoclase.)

IV. Orthoclase from Brazil. Analyzed by v. Hauer (Kenngott's Uebersichte, etc., 1856-7, p. 106. Cited after Descriptive Mineralogy, by J. D. Dana, 1868, p. 357).

It is evident from the above analyses that the soluble and insoluble parts may well be considered as consisting of eleolite and orthoclase respectively.

F. A. Genth of Philadelphia made the first analysis of this pseudomorphic material from Magnet Cove and the results of his examination were published by G. F. Kunz in a paper entitled "A pseudomorph of feldspar after leucite(?) from Magnet Cove, Arkansas."*

In this paper Kunz describes the mineral as it occurs in its most weathered form. It was of such a crystal that Genth made his analysis, and consequently his results correspond more nearly with the analysis of similar material from Oberwiesenthal and Vogelsberg than with those of fresh material from the Arkansas rock.

It is apparent that the material which Genth analyzed is very unlike that used by the writer in his experiments and hence no direct comparison between the two can be made. Both specimens show, however, that leucite is the mineral from which the pseudomorphs were formed. These analyses show that eleolite is present in much smaller quantities in the large, much decomposed crystals than in the smaller, fresh ones and with this conclusion the results obtained from the optic examination entirely agree.

The result of Genth's analyses, which he compares with

* Proceedings of the A. A. A. S., Vol. XXXIV., Ann Arbor meeting. 1885. Salem, Mass., 1886, pp. 242-246.

Also Am. Jour. Sci., Series 3, Vol. XXXI., 1886, p. 74.

those of Bergemann* from Oberweisenthal and Knop† from Vogelsberg, are as follows:—

Analyses of altered leucite from various localities.

CONSTITUENTS.	Magnet Cove. Genth (*)	Oberwiesenthal Bergemann. (†)	Vogelsberg. Knop.
SiO_2	60.77	60.46	56.61
Al_2O_3	22.13	22.11	22.92
Fe_2O_3	0.44	1.98(‡)	2.33
MgO	0.05	1.22	.....
K_2O	13.91	13.53	13.65
Na_2O	0.36	0.51	2.95
H_2O	2.95	.....	CaO 1.69
	100.61	98.81	.....

(*) The mean of Genth's two analyses only is given.

(†) Kunz probably took this analysis from Dana's Mineralogy, 1868., p. 384. Bergemann states that 1.217 per cent of water was given off on ignition. He considers the ferric oxide (Fe_2O_3) an impurity but retains the ferrous oxide (FeO) in the analysis. Bergemann treated the coarsely powdered material with very dilute, cold hydrochloric acid and obtained 5.96 per cent soluble and 93.86 per cent insoluble matter. The analysis given above is the sum of the analyses of these two portions. Rammelsberg in quoting this analysis (Mineralchemie, 1875, p. 444) gives the iron as oxide (Fe_2O_3—2.20) and adds in the 1.22 per cent of water (H_2O—1.22) making a total of 101.26.

(‡) Fe_2O_3—1.98 should read FeO—1.98.

The crystal which was analyzed by Genth was examined optically by G. P. Merrill of Washington and the description of the sections studied by him correspond in all particulars with observations made by the writer on the medial section of the large, decomposed crystal mentioned above. Merrill (see paper by Kunz, p. 244) says:—"From my examination of the thin section I find the structure quite homogeneous, but spherulitic, nearly the entire mass being made up of the small, spherulitic bodies shown in the photograph (not reproduced). These bodies, which are a millimeter, or upwards, in diameter, consist of a central, nearly colorless, mass, non-dichroic, but giving the polarization of an aggregate in faint, iridescent colors. This center is, in many cases, stained yellowish by metallic oxides. Beyond the center is a zone consisting of radiating, columnar bodies of indefinite outline, giving no colors between crossed

* Ueber eine Pseudomorphie des Leucits, von C. Bergemann. Journal f. prakt. Chemie, Band. LXXX., 1860, p. 418.

† Jahrbuch f. Mineralogie, Jahrg. 1865, p. 485.

nicols but showing their greatest extinction nearly always parallel to lines drawn from the center of the spherulite toward the circumference. The spaces between these columnar bodies are filled with the same colorless aggregate as the central portions of the spherulites. These last, it may be stated, are not in all cases spherical in outline, but often irregularly elongated, having evidently interfered with one another in process of formation. Those towards the center of the crystal are most elongated, while those toward the outer portion of the crystal are less closely compacted and hence possess a circular outline, as seen in the plate. The difference in shape is, so far as I can determine, the only distinguishing feature between the outer crust of the pseudomorph and the more compact interior.

"What I have written, you perceive, furnishes no clew whatever as to what the original mineral may have been, and I am able to obtain no measurement of extinction or crystallographic angles that shall help me in the least."

In the conclusion of the paper Kunz suggests that from the fact that the outer shell of these crystals breaks off easily they may be alterations of garnets and adds that the point of breaking may be the point of contact of the garnet with schorlomite which is usually inclosed in it. He says, however, that the similarity between the analysis of this material and that made by Bergemann of a feldspar pseudomorph (closely resembling oligoclase in composition) after leucite from the Oberwiesenthal in Bohemia (l. c.) suggests very strongly the identity of the two minerals and the derivation of the Magnet Cove pseudomorph from leucite. Kunz then suggests the possibility of the existence of large quantities of this mineral at the Cove (See page 208).

An occurrence of crystals similar to the pseudoleucites has been described by Hussak * from Brazil in a letter to the editor of the the Neues Jahrbuch für Mineralogie.

The *groundmass* of the leucite syenite resembles very closely the eleolite porphyry already described (See p. 259). It is a hypidiomorphic granular mixture of eleolite, orthoclase,

* Ueber Leucit-Pseudokrystalle im Phonolith (Tingualte) der Serra de Tingua, Estado Rio de Janeiro, Brazil, von E. Hussak. N. Jahrb. für Mineralogie. Jahrgang 1890, Band I, pg. 167.

pyroxene, biotite and melanite in which the eleolite is by far the most prominent member. It appears as phenocrysts in a fine-grained base consisting of smaller, idiomophic eleolite, biotite and melanite crystals.

Eleolite occurs in idiomorphic crystals of a short prismatic form and differs in no respect from that already described. In inclusions and decomposition products it is also identical with other eleolite crystals. Their size is the only indication that the crystals are of a younger generation than the larger crystals since they are idiomorphic in form.

Orthoclase is scarce and appears in small translucent crystals tabular parallel to the clinopinacoid (010) which are generally twinned according to the Carlsbad law. The optic axis angle is rather small, but not as small as that usually found in sanidine and as the glassy appearance is entirely wanting the mineral may better be classed as orthoclase than as the latter.

Sodalite has not been observed under the microscope but from the amount of NaCl (0.54 per cent) which was found in the chemical examination of the rock it is probable that it is present although not optically distinguishable.

Pyroxene. Two minerals which belong under the head of pyroxene have been observed; the more important of these is a comparatively large-grained diopside which shows considerable pleochroism and is generally bounded by a darker green band. Its angle of extinction is usually about 40° and in other respects its characteristics correspond very closely to those of the same mineral described in other rocks from the same locality.

Ægirite also occurs in small crystals which are of a decided green color under the microscope and show a small angle of extinction. It is evident that these crystals are of late formation and are probably of secondary orgin. In some cases they show very distinctly that they have been formed by the decomposition of the diopside.

Biotite occurs in thick, irregularly bounded plates which seldom exceed one millimeter in diameter. They show the corrosive action of the magma in which they were formed and are, also, often much decomposed about the edges.

Melanite is found in varying quantities in the different specimens. In some it is almost entirely wanting while in others it forms a very important factor. It is of a rich brown or yellowish brown color, decidedly zonal in its structure and isotropic in its optic properties. It is usually idiomorphically bounded and is often penetrated by eleolite crystals causing it to present a decided ocellar structure. In some cases more than half the area inclosed within the boundaries of the section consists of melanite material.

Titanite in idiomorphic crystals and magnetite in small grains are common. *Pyrite* also often occurs.

The decomposition products common to the eleolite syenite occur in considerable quantities. Thus, cancrinite, calcite, and undetermined zeolites are often present in large numbers.

From the following chemical analysis (I) the leucite syenite dike rock is seen to be very closely allied to the eleolite syenite of the Diamond Joe type (II). In order to show this similarity the two analyses are placed side by side.

Comparison of analyses of leucite syenite and eleolite syenite from Magnet Cove.

CONSTITUENTS.	I. Leucite syenite dike rock.	II. Eleolite syenite dike rock.	
SiO_2	50.96	53.38	
TiO_2	0.52	.....	
Al_2O_3	19.67	20.22	
Fe_2O_3	7.76	1.56	4.95 Fe_2O_3
FeO	.....	1.99	
FeS_2	.....	1.77	
MnO	Trace	Trace	
CaO	4.38	3.29	
MgO	0.36	0.29	
K_2O	6.77	6.21	
Na_2O	7.67	7.89	
NaCl	0.54	(?)	
SO_3	Trace	.....	
Loss on ignition incl. CO_2	1.38(*)	3.43	
Total	100.01	100.06	

(*) Material dried at 135° C.

I. Leucite syenite from near Diamond Jo quarry, Magnet Cove, analy. by W. A. Noyes.

II. Eleolite syenite from Diamond Jo quarry, Magnet Cove, analy. by R. N. Brackett. (See page 238).

The silica of the leucite syenite is two and a half per cent lower than that of the eleolite syenite, but the other constituents, and especially the alkalies, are present in such nearly equal quantities that it is probable that the two rocks were formed from the same magma.

This view is further substantiated by the fact that the two rock pass into each other without showing any line of separation whatever. In the large block of stone west of the Diamond Jo quarry this can be well seen (figure 10, page 199). The figure was drawn from a photograph of this boulder in order to show the gradual transition from the leucite into the eleolite syenite but the attempt was not wholly successful.

The eleolite rock appears to have cooled last because in every case where it is observed in conjunction with the leucite rock it is seen to have formed a sort of flow structure around the latter.

Many varieties of both the eleolite syenite dike rock and the leucite syenite dike rock show a movement in the magma during the cooling and are, therefore, properly classed among the intrusive dike rocks.

2. *Leucite Tinguáite.*

a. Border Type.

This type differs from the "dike type" (p. 281), the description of which will follow, both in its structure and mode of occurrence. It forms a mass of rock which is in all probability the border of a larger mass of leucite syenite dike rock and shows in its structure no indications of flow, as the dike type does. It also differs from the latter in its macroscopic appearance for in no case does it show the glassy fracture so characteristic of the dike type and which causes the latter to bear such a strong resemblance to phonolite.

The leucite tinguáite is found in both green and black

varieties and in some of its forms might easily be mistaken for a metamorphosed sedimentary formation were it not for the more or less distinct pseudoleucite crystals which appear in it. The black variety containing comparatively distinct pseudoleucite crystals is almost identical with that from Brazil, and on comparing specimens from the two localities the greatest similarity is observed.

The Brazilian rocks * of this type have been studied and described by Graeff † and by Machado ‡ without the detection of the true character of the large icositetrahedral masses. Dr. E. Hussak has been working upon the igneous rocks of Brazil in connection with Mr. O. A. Derby, for some time and a short resumé of their work was read by Derby before the American Association for the Advancement of Science at the Indianapolis meeting in 1890 ||. In this Derby describes briefly the Brazilian localities in which the granitic type of nepheline syenite, or foyaite, occurs associated with typical volcanic eruptives in such a way as to show that it is a volcanic rock in the most restricted sense of the term. Moreover the habit of many of the foyaite masses is that of a lava flow. Specimens and photographs of peculiar polyhedral inclusions or pseudo-crystals having the form but not the substance of leucite and consisting of coarse-grained foyaite imbedded in a fine-grained phonolitic groundmass were exhibited.

It thus appears that Hussak and Derby found the "in-

* The writer is greatly indebted to Dr. George H. Williams of John Hopkins University for a specimen of rock similar to this leucite tinguáite and from the already renowned Brazilian locality, also to Mr. Orville A. Derby, Director of the Geological Commission of São Paulo, Brazil, with whom he spent several days in comparing the rocks from the Brazilian and Arkansas regions. Mr. Derby has made many valuable suggestions which have been gladly adopted by the writer and which have been made use of in this report in such a way that it has been impossible in every case to give the credit where it is really due.

† Mineralogisch-petrographische Untersuchung von Eläolithsyeniten von der Serra de Tinguá, Prov. Rio de Janeiro, Brazilien, von Franz Fr. Graeff. N. Jahrb. für Min. Jahrg. 1887, Band II., p. 255.

‡ Petrographie der südwestlichen Grenze zwischen Minas-Geraës und S. Paulo von Jordano Machado. Min. u. Pet. Mitth. Band IX., 1888, p. 347.

‖ Proceedings of the A. A. A. S,, Indianapolis Meeting, 1890, Vol. XXXIX., Salem, 1891.

clusions" to have been originally leucite crystals which contain no longer the leucite material but a mixture of minerals which approaches the eleolite syenite in its composition.

Green variety.—This rock consists of a dense green groundmass in which are scattered large phenocrysts of pseudoleucite. These are often 5cm and more in diameter. By exercising great care these may be broken out from the rock in such a manner as to show a few sharp crystal faces but perfect crystals have not been obtained.

The fracture of the rock is dull and it shows, even macroscopically, that the groundmass consists of a holocrystalline mass of minute crystals which shows no tendency towards a fluidal structure. In some cases there are large phenocrysts of biotite but they are rare. Jet black, shining sections of melanite also occasionally occur. Eleolite appears in large phenocrysts and often penetrates both the pseudoleucites and the groundmass.

Under the microscope the complete absence of fluidal structure is a very striking feature. The base is seen to be made up of a hypidiomorphic nearly panidiomorphic granular mass of eleolite, ægirite, biotite, and melanite.

Pseudoleucite crystals occur as large phenocrysts and are in every respect identical with those already described (p. 268).

Eleolite and its decomposition products make up the body of the groundmass through which are scattered idiomorphic ægirite needles which give the green color to the rock. Biotite occurs in brown plates of two generations but is not very plentiful. Melanite appears as usual in small, irregular or idiomorphic crystals and plays but an unimportant part in the composition of the rock. The accessory minerals and decomposition products are identical with those described in the leucite syenite dike rock and the eleolite syenite dike rock (Diamond Jo type).

Spotted variety (black with white spots).—In some cases a rock very similar to that just described occurs in which the

base is black rather than green. The change in color is due to the somewhat increased size of the ægirite crystals and to the occurrence of a greater quantity of magnetite in the base. Melanite and pyrite appear more commonly in this rock than in the preceding variety and in some cases an apparently secondary generation of pseudoleucites has taken place. Several specimens of pseudoleucite crystals have been obtained from this rock which are perfect icositetrahedrons with smooth faces and sharp edges and corners. In perfection of exterior form they can hardly be surpassed by the true leucites of the effusive leucitites, but in the interior they are completely pseudomorphosed.

Black variety (black with "suggested" leucites).—This rock is one of the most peculiar of the whole group. It appears, on the whole, as a black and dense mass and might easily be mistaken for a metamorphosed sedimentary rock were it not for the fact that scattered through it at irregular intervals are large "suggested" pseudoleucites. These are of almost or quite the same color as the groundmass and can hardly be distinguished from it either macroscopically or microscopically. They are often several centimeters in diameter and in a few cases have been broken out from the groundmass in perfect forms. Under the microscope the rock is extremely uninteresting and unsatisfactory. It is made up of a confused mass of small crystals whose optic characteristics as well as their crystal forms are very much obscured. The pseudoleucites do not differ materially from the groundmass in structure or in mineralogic composition and their existence could not be detected by the use of the microscope alone. It is only when they are known to be present from macroscopic observation that an infinitesimal variation between them and the groundmass can be detected under the microscope. It is for this reason that the name "*suggested*" has been used to distinguish them for in truth they contain no leucite material proper and yet their form is in some cases found to be perfect. There is no possible doubt but that the rock is of igneous origin, but the forma-

tion of these extremely impure pseudoleucites is an interesting and puzzling question. The facts indicate that like other pseudoleucites they began to form under conditions favorable to the formation of leucite and, as is frequently the case with true leucite crystals, they included all sorts of foreign particles such as magnetite, ægirite, etc. The conditions then changed and instead of becoming true leucites their substance was recrystallized and the leucite molecule was broken up into eleolite and orthoclase. (See page 271.)

The groundmass of this black variety of leucite tinguáite is so indefinite in its crystallization that few of the minerals of which it is composed can be determined with any accuracy. The following have, however, been identified with some degree of certainty.

Eleolite is probably present for when a section is etched with hydrochloric acid small salt cubes are formed. Orthoclase or sanidine appears in distinctly bounded lath-shaped sections which often show a Carlsbad twin structure. Ægirite and diopside are both visible and biotite appears in brown plates which are possibly of secondary origin. It is evident from the above description that the rock belongs in the group of leucite tinguáites, but it is upon the whole unsatisfactory and from a microscopic point of view uninteresting.

b. Dike Type.

The dike type of leucite tinguáite occurs as a yellowish green or greenish black, dense rock usually containing white phenocrysts of pseudoleucite, eleolite and feldspar, but is sometimes almost free from them. It is porphyritic and often shows a fluidal structure even in a hand specimen. It breaks easily and with a hornstone-like fracture.

Under the microscope the porphyritic and fluidal structure is still more conspicuous than in the hand specimen. The groundmass is holocrystalline and consists of numberless small green pyroxene crystals arranged with a fluidal structure through a base made up of numberless lath-shaped feld-

spar and nepheline (?) crystals which seldom exceed 0.1 millimeter in length. In many parts of the section the feldspar crystals seem to have had a tendency to form large phenocrysts, but to have been prevented by the premature cooling of the rock. Spots occur where the crystals of the groundmass for a distance of half a millimeter or more have the same extinction and appear like one incomplete crystal.

Sanidine of the first generation (phenocrysts) appears as white, glassy, transparent crystals which are thin tabular parallel to the symmetry-plane and often reach a size of 30 or 40 millimeters.

The faces that have been observed are $\infty P\bar{\infty}$ (010), ∞P (110), $\infty P\frac{3}{2}$ (130); $0P$ (001) and $+P$ ($11\bar{1}$). The crystals are often twinned according to the Carlsbad law.

Under the microscope they usually appear as transparent, fresh sections whose form indicates that they have been cut from tabular crystals. Around the edges, although usually sharply defined, they show the corrosive action of the magma on the crystals and the small needles of pyroxene are often found penetrating them and the groundmass at the same time. A zonal structure is not uncommon. In some cases the crystals are weathered and resemble orthoclase crystals in which kaolinization has taken place.

Cleavage is observed parallel to the usual planes and also an indistinct separation parallel to the orthopinacoid (100) has been noted in a few cases. On the whole the cleavage cracks are not as common as might be expected. In some cases the crystals have been broken and the separate parts have moved past each other in such a way as to indicate that there was a movement in the magma after the fracture took place. In convergent polarized light the crystals are usually found to have a small optic axis angle although in some cases it has been observed as large as 50°. The optic axes generally lie in the clinodiagonal plane, but in a few cases they have been observed in a plane at right angles to it.

Inclusions of gas and liquids are seldom observed, but when they occur they form bands traversing the crystal.

Sanidine of the second generation consists of small lath-like crystals which seldom exceed 0.15mm in length and are hardly one tenth of that amount in thickness. They are generally sharply terminated on the sides, but the ends are often frayed out and indistinct. Carlsbad twins are common, in fact more common than single crystals. Their extinction is usually wave-like and is different for different parts of the section. The crystals often gives the appearance of a plagioclase instead of sanidine. These small crystals are penetrated in all directions by ægirite needles, but are comparatively free from inclusions of other sorts and seldom show any indication of decomposition.

Pyroxene occurs among the phenocrysts and as a part of the groundmass. In the first class it is unimportant in quantity for it is only rarely that a crystal occurs. In a thin section whose surface was about 3 square centimeters only eight crystals of the earlier generation were discovered while in another of about the same size only six crystals were observed.

The phenocrysts appear under the microscope as green, somewhat pleochroitic, idiomorphically bounded crystals or portions of crystals which show by their comparatively small (not over 15°) angle of extinction that they belong to the ægirite group. Included in these and completely surrounded by them crystals of a lighter, yellowish green color often occur in which the pleochroism is very slight, but the angle of extinction is large. In some cases the extinction angle of this interior portion reaches 35° and it is probable that these crystals are diopside. The diopside occurs also without the surrounding band of ægirite and it then generally forms somewhat thicker prisms.

The cleavage, inclusions, etc., of both these forms of pyroxene are so similar to those already described for other occurences of these minerals that they need not be repeated.

Ægirite of the second generation occurs in extremely small, prismatic and acicular crystals scattered thickly through the base and often showing a very distinct fluidal structure. It is these minute green crystals that give to the rock its green color

and in cases where they assume a dark green color the rock becomes black.* It is evident from their form and arrangement these minute prisms were formed after the phenocrysts but before the sanidine of the base for they are usually perfectly idiomorphic and show that a decided flow of the magma took place around the phenocrysts during and after the time that they were forming. Small crystals show that the faces ∞P (110) and $\infty P\bar{\infty}$ (100) are present and in many cases the angle ∞P (110): ∞P (110) is seen to be approximately 87°. When the crystals are inclined to the plane of the section and are cut by it they usually show sharpened points which might easily be mistaken for crystal faces, but when they lie parallel to the plane of the section they are seen to be frayed out and indistinct at the ends. Thin sections of the rock show the green color of the small crystals very distinctly and, if they are not too minute, allow of the determination of a slight pleochroism with a change of color corresponding to that usually observed in ægirite. The extinction angle is small, seldom exceeding 5°.

Eleolite or nepheline occurs in two generations and often forms large phenocrysts which are easily distinguishable by the naked eye. The crystals range from 10 millimeters in diameter down to microscopic dimensions and are characterized by their greasy appearance, irregular fracture and white or pinkish color. They are are idiomorphic and thick prismatic in form and show the usual cleavage and microscopic structure of this mineral. Decomposition seems to have been very busy in many cases and it is not uncommon to find sections which have been almost completely altered into indistinguishable secondary minerals.

The *secondary nepheline*, which in connection with sanidine forms the groundmass, occurs in allotriomorphic crystals which are perforated in all directions by the ægirite crystals and bounded by the sanidine and other nepheline crystals.

They are very often altered to cancrinate which is easily detected by its high polarization colors and effervescence with acids as already described (page 235).

Pseudoleucite occurs also in two generations, but it is much

* See Graeff, Eläolithsyeniten, etc., l. c., p. 256.

more difficult to make a sharp distinction between them than in the case of the sanidine and nepheline. Those crystals which are evidently of the first generation are characterized microscopically by their large size and distinct icositetrahedral form. These crystals when fractured show a pure white interior and appears to be fine-grained and homogeneous, but when studied under the microscope they are found to consist of minute feldspar crystals interspersed with small particles of eleolite. The spheroidal structure is entirely wanting and in fact it seems as if this were directly connected with the weathering which has taken place in many crystals and not with the pseudomorphic influences, whatever they may be, that have altered the constitution of the crystals.

The small pseudoleucites contain many of the small secondary ægirite crystals and are much less sharp in their forms. It is, however, by no means certain that these really belong to a second generation, but from the fact that they are interbedded among the other minerals of the groundmass it seems probable that this is the case.

Cleavage and microstructure, in the true sense of the words, can hardly be considered for they belong really more to the individuals of which the crystal is now made up than to the pseudoleucite itself. The same is true of their decomposition products and it is usually found that where these have formed they are divided into those which are characteristic for eleolite (cancrinite, etc.), and those which are usually associated with orthoclase (kaolin, etc.). Cancrinite and calcite are often found and in some cases form a very important part of the pseudomorphs.

Sodalite group.—In many cases the existence of some members of this group or of the haüyne group is suggested by the appearance of six and eight sided, apparently regular, sections in the green groundmass. On a close investigation these are all found to consist of secondary decomposition products usually resembling those which occur in the pseudoleucites, but in some cases they appear to be of a different constitution. From the chemical analyses made of this rock it is probable that members of both the sodalite and haüyne group exist in it to a

limited extent for both chlorine and sulphuric acid are found in appreciable quantities.

Pyrite is common in these rocks and especially so in the black varieties. That its quantity is not inconsiderable is shown by the chemical analysis.

Magnetite and ilmenite occur only in single, isolated crystals which are far from plentiful.

Biotite appears to be entirely wanting or to be present only as a secondary product and in very limited quantities. Where it has been observed it is normal biotite and has an optic axis angle of 2° to 3°. The plane of the optic axes is parallel to the symmetry-plane.

Chemical analyses have been made of two specimens of this rock which differ considerably in their microscopic appearance. The first analysis (I) was made on a dense, close-grained, green, hornstone-like rock in which no phenocrysts whatever are observed.

Analysis (II) was made from material in which large white phenocrysts of pseudoleucite and sanidine are visible. It was conducted in the same way as the analysis of the pseudoleucite crystal and the results of both the soluble and insoluble parts were calculated to 100 as shown in the table.

It is evident from column II. that minerals containing both chlorine and sulphuric acid are present.

The soluble portion of the rock (column IV or VII) would naturally contain the easily soluble minerals, sodalite, haüyne, and nepheline; if therefore the chlorine be considered as belonging entirely to sodalite and the sulphuric acid to haüyne and the amounts of the minerals corresponding respectively to these substances be calculated and their constituents (VIII, IX and X) deducted from the corresponding constituents in the analysis of the soluble portion of the rock (VII) the remainders should represent the amount of the constituents of the mineral nepheline (eleolite) (XI). If this result is then recalculated to 100 per cent (XII) and compared with the theoretical composition of eleolite (nepheline) (XIII), it appears that the soluble portion of the rock consists principally of these three minerals.

Analyses of leucite tinguáite (dike type).

CONSTITUENTS.	I. Complete analysis. Dense rock.	II. Complete analysis. Rock with Phenocrysts.	III. Analysis of soluble part of same.	IV. Same recalculated to 100 per cent.	V. Insol. part (by difference) recalculated to 100 per cent.	VI. Ægirite tinguáite. Norway.
SiO_2	54.04	52.91	14.35	38.32	61.27	56.58
TiO_2	.....	none	.....	.....	.....	.....
X (*)	.....	0.48	.....	.....	.....	.....
Al_2O_3	20.27	19.49	11.72	31.24	23·95	19.89
Fe_2O_3	4.66	4.78				3.18
FeO	0.64	2.05	.....	.....	.....	.....
CaO	2.75	2.47	.....	.....	.....	0.56
SrO	.....	0.09	(0.43) by dif.	1.44	4.54	1.10
MgO	0.16	0.29				0.13
MnO	.....	0.44	.....	.....	.....	0.47
K_2O	6.79	7.88	1.43	3.82	10.24	5.43
Na_2O	8.56	7.13	7.19	19.20	.....	10.72
Li_2O	.....	trace	trace	.....	.....	.....
H_2O (ignition)	1.93	1.19	(1.19)	3.18	.....	1.77
CO_2	.....	none	none	.....	.....	.....
Cl	.....	0.53	0.53	1.41	.....	.....
SO_3	.....	0.52	0.52	1.39	.....	.....
P_2O_5	.....	trace	trace	trace	.....	.....
Total	99.80	100.25	37.36	100.00	100.00	99.83

(*) For explanation of use of X see page 226.

I. Complete analysis of dense green leucite tinguáite by R. N. Brackett.

II. Total analysis of leucite tinguáite by J. F. Williams.

III. Analysis of soluble portion of leucite tinguáite by J. F. Williams.

IV. Analysis of soluble portion of above recalculated to 100 per cent.

V. Analysis of insoluble portions (by difference) recalculated to 100 per cent. This shows at once a strong likeness to an analysis of orthoclase, but the silica and potash are too low and the groups of the other constituents too high. This indicates the presence of considerable quantities of basic silicates. If these were deducted the analysis (V) would approach, very closely, that of orthoclase.

VI. Analysis of ægirite tinguáite from Asbjörnsröd, Hedrum, Norway, analyzed by G. Paijkull (Syenitpegmatitgänge, p. 41).

Table showing approximate composition of soluble portion of leucite tinguáite (dike type.)

CONSTITUENTS.	VII. Complete analysis	VIII Sodalite deduction	IX. Haüyne deduction	X. Sum of deduction	XI. Resulting analysis	XII. Same recalculated	XIII. Theoretical eleolite
SiO_2	38.32	7.14	4.17	11.31	27.01	41.58	41.24
Al_2O_3	31.24	6.12	3.57	9.69	21.55	33.10	35.26
CaO	1.44(?)	.....	0.53	0.53	0.91	1.40	.....
K_2O	3.82	.....	.....	.....	3.82	5.90	6.46
Na_2O	19.20	4.98	2.64	7.57	11.68	17.75	17.04
H_2O	3.18	.....	.....	(3.00)	0.18	0.27	.....
Cl	1.41	1.41	.....	1.41	0.00	.....	.....
SO_3	1.39	.....	.....	1.39	0.00	.....	.....
Per cent.	100.00	19.60	12.30	34.90	65.10	100.00	100.00

VII. Analysis of soluble portion of leucite tinguáite by J. F. Williams. (See IV above).

VIII. The figures represent the amounts of the other constituents of sodalite which correspond to 1.41 per cent. of chlorine *.

The number at the foot of the column represents the percentage of the whole rock that the sodalite forms.

IX. The figures represent the amounts of the other constituents of haüyne which correspond to 1.39 per cent. of sulphuric anhydride *. The number at the foot of the column represents the percentage of the whole rock that the haüyne forms.

*The theoretical analyses of sodalite and haüyne are expressed by the following per cents: (Rammelsberg, Mineralchemie, 1875, pp. 453 and 457).

Theoretical analyses of soladite and haüyne.

CONSTITUENTS.	VII a. Theoretical sodalite.	IX a. Theoretical haüyne
SiO_2	37.08	33.89
Al_2O_3	31.71	29.00
CaO	.....	4.31
Na_2O	25.55	21.50
Cl	7.31	.....
SO_3	.....	11.30
Total	101.65	100.00

X. Sums of several constituents of the preceding columns (VIII and IX).

XI. Remainder after subtracting the several constituents of the preceding column (X) from the constituents in the original partial analysis (VII or IV). The number at the foot of the column represents the percentage of the whole rock that the eleolite (nepheline) forms.

XII. Column XI recalculated to one hundred per cent.

XIII. Theoretical analysis of eleolite as calculated from the formula $(4Na, K)_2 Al_2 Si_2 O_8$ which represents very closely the composition of the eleolite from Magnet Cove. Analyzed by Smith and Brush (See p. 210).

If the amounts of sodalite, haüyne and eleolite as estimated above be expressed in percentages of the whole rock and the insoluble parts be considered as made up of orthoclase and ægirite * in the ratio of about 3 to 1. The quantitative mineral composition of the leucite tinguáite would then be expressed, approximately, by the following table:—

Approximate mineral composition of leucite tinguáite.

Sodalite	7.57	
Haüyne	4.71	
Eleolite	25.08	
Ægirite	15.66	62.64
Orthoclase	46.98	
Total	100.00	

The rocks of the tinguáite group have been but little studied and but few analysis of them have been made. It is, however, probable that some of the rocks described as phonolites will be found upon further investigation to fall under the tinguáite group.

The only analysis of a tinguáite which is available is that of the Norwegian ægirite tinguáite (VI) described by Brögger (Syenitpegmatitgänge, p. 41). This is, however, not strikingly like the leucite tinguáite of Magnet Cove in its composition.

* The absence of soda in the insoluble part does not correspond with the assumption that the minute green pyroxene crystals are ægirite, but as all the constituents of the insoluble parts were determined by difference, a small error in the determination of the soda in the complete analysis or that of the soluble part would make a relatively great difference in the soda of the insoluble part.

III. PETROGRAPHIC DESCRIPTION OF AUGITIC ROCKS.

A. Fourchite Group.

Many dikes of augitic rock occur here and there among the hills about the edge of the Cove. These are usually exposed in the beds of the streams and are very seldom capable of being traced for any considerable distance on either side. They are mentioned in the general description of the Cove and their mineralogic constitution and individual peculiarities are in many cases described by J. F. Kemp in Chapter XII. of this report.

In general these dikes may be grouped into two classes, viz: those in which large, tabular biotite crystals occur forming the so-called ouachitite and those in which this mineral is almost or completely absent. The mineralogic composition and structure of these two varieties is identical in all but this one respect. The second of these varieties is often very fine-grained and it is quite impossible to determine without the microscope whether it is a fourchite or a dense dike form of eleolite porphyry. A large number of these augitic dikes have already been found and examined, but it is probable that not a tenth, nor even a hundredth, part of those that exist are exposed and visible. It is, therefore, a matter of little consequence whether the exact composition and structure of each one of those found, has been determined under the microscope, especially since there exist so many more which have not been discovered. A microscopic examination has been made of many of the dikes which have been discovered and the results of these investigations are tabulated in Chapter XIII. of this report.

Where the fourchite and ouachitite come in contact with the other igneous rocks they, like those of Fourche Mountain area, are older than the youngest syenite rocks and are cut by them.

B. Monchiquite Group.

Amphibole monchiquite is known from only one locality in the Magnet Cove region and that is inside the cove itself. It

cuts across the northern part of the inside of the basin in a nearly east and west direction and extends for several hundred meters (see page 185 and chapter XIII., dike 159).

It is a dark colored, heavy rock which, microscopically, appears comparatively uniform in texture except, here and there, where black, shining amphibole prisms (2 to 3mm in length) and small (1 to 1.5mm in diameter) greenish yellow olivine crystals occur.

Under the microscope the most conspicuous objects are the large phenocrysts of perfectly fresh olivine. These together with large augite and amphibole crystals form the most important minerals in this prophyritic rock and are distinctly separated from the fine-grained, holocrystalline base which shows a somewhat fluidal structure.

Olivine is by far the most important and characteristic mineral of the rock. It appears in greenish yellow grains which show a waxy lustre on their broken surfaces. Exterior crystal forms cannot be seen macroscopically on account of their small size. In thin sections, under the microscope the olivine appears as colorless, transparent, non-pleochroitic, idiomorphic crystals which are irregularly distributed throughout the section, being more numerous in certain bands and spots than in others. The crystals may be said to be truly idiomorphic although they are usually resorbed about the edges and show that the magma in which they floated was sufficiently acid to have a strong corroding action upon them.

Cleavage cracks are distinct although not frequent and those parallel to the brachypinacoid (010) are much more distinct than those parallel to the macropinacoid (100). Along these cleavage cracks a slight decomposition has taken place, indicated by a yellow coloration of the adjacent parts of the crystal.

The crystals are not uncommonly made up of two individuals and, so far as they have been observed, they seem to be twinned with the brachydome (011) as the composition plane.

In parallel non-polarized light the crystals appear colorless and transparent and have a rough surface showing that the index of refraction is higher than that of Canada balsam. The inter-

ference colors are high, reaching even to those of the third order. The extinction is orientated in sections not too greatly inclined to the symmetry-planes. In convergent polarized light one optic axis is often seen, but in no case has a section showing two axes been observed. From this fact it is seen that the optic axis angle is large and consequently no observations on the character of the dispersion of the axes or the bisectrices were possible.

The crystals are remarkably free from inclusions of all sorts and seldom show anything more than a few grains of magnetite and pyrite disseminated through them. A few regularly bounded gas inclusions occasionally appear in the crystals, but in no case have liquid inclusions been observed. As has already been stated these crystals show slight indications of weathering and along the cleavage cracks a deposition of a yellow, hydrous oxide of iron often occurs. Alteration to serpentine has not been noticed in any case.

Pyroxene is the most important mineral, in respect to quantity, in this rock. It makes up at least half of the mass of the rock and occurs in two generations. The older phenocrysts are in every respect identical with those described by Kemp in Chapter XII. of this report and like them belong to the class of basaltic augites. They have the same purplish tinge and appear as twins and single individuals in the same way that they do in the fourchite and ouachitite. They differ, however, from these in that, since they are later in the period of their formation than the olivine and amphibole phenocrysts, they are allotriomorphic wherever they come in contact with these minerals. In the fourchite, on the other hand, they were the oldest of all the silicates and were therefore always idiomorphic.

The augite of the second generation forms small crystals having a similar appearance to the larger ones; they are idiomorphic whenever they do not come in contact with the olivine, hornblende or augite phenocrysts. They, like the older generation, contain magnetite grains and gas inclusions, but very rarely show any sign of decomposition.

Amphibole occurs in black, shining prisms which sometimes attain a length of several millimeters. This mineral appears to

be especially frequent in some parts of the rock and to be entirely wanting in other parts of the same specimen. Under the microscope it is seen to occur in both large and small, prismatic crystals of two generations.

The cleavage parallel to the prisms (110) is very perfect, but the cleavage cracks are not near together. They make the characteristic angle of 124° 30′ with each other and appear in the vertical sections as distinct cracks parallel to the vertical axis. Cleavage planes appear which are quite irregular, making various angles with the first and lying in the same general direction as the base (001).

The crystals are of a brown color when seen in parallel non-polarized light. They are strongly pleochroitic, the colors varying from yellow to dark reddish brown. The pleochroism is represented by the following formula:—

$$c > b > a$$

The positions of the axes of greatest and least elasticity are the same as those usually observed for basaltic hornblende to which variety of amphibole these crystals belong. The acute bisectrix makes an angle of 13° with the vertical axis c and lies in the acute angle β. The character of the double refraction is positive. The large phenocrysts are perfectly idiomorphic and are older than any of the other constituents except the olivine. The smaller crystals of the second generation are on the contrary younger than the augite and often form around the latter or else appear as small allotriomorphic crystals wedged in between two or more of the augite phenocrysts; they are, however, older than the augites of the second generation. In some cases the phenocrysts of amphibole are surrounded by an indistinct flow structure and it is evident from this and from the fact that they not uncommonly show a slight bending and fracture with a separation of the broken parts that there was a movement in the magma after they were formed. In parts of the rock where much olivine exists the amphibole phenocrysts appear to be very scarce or to be absent entirely and *vice versa*. It may be that this is only accidental, but as it is quite uniformly the case it appears to be characteristic of the two minerals.

Both the phenocrysts and second generation crystals contain numerous inclusions of gas and of some white, transparent mineral which resembles apatite. *Magnetite* occurs in black grains and crystals in considerable quantities.

Plagioclase occurs in small lath-like crystals which seldom exceed 0.2mm in length and are usually much smaller. Their width is not more than one-tenth, rarely two-tenths, of their length. They are occasionally idiomorphically terminated in the prismatic zone, but the faces which bound them can hardly be determined on account of their minuteness. It is evident, however that the brachypinacoid (010) prisms (110) and the base (001) are present. In some cases the ends of the crystals are sharply truncated, but they are more often frayed out and irregular.

In parallel polarized light the crystals are seen to contain a number of twin lamellæ which run directly through them parallel to the brachypinacoid (010) and which show large angles of extinction on both sides of the composition plane. In all cases where these angles have been measured they have been found to lie between 30° and 35° and to indicate a plagioclase very rich in lime and approaching an anorthite in its composition.

The crystals appear often in an irregular fluidal structure and indicate that the magma in which they were formed was still mobile. The groundmass occupies the space about the minerals already described. It is colorless and shows that it has assumed a semi-crystalline structure, from the fact that between crossed nicols it has an undulatory extinction which often indicates a spheroidal structure. By means of a selenite plate this structure is more clearly seen. None of the original glass seems to have been preserved, but it appears to have all become crystalline. In certain cases there appear in this groundmass very minute prisms which have an orientated extinction and resemble nepheline. They show negative double refraction, but are too minute to be tested microchemically. The altered groundmass is readily acted upon by hydrochloric acid and when tested with fuchsine solution shows a strong red color

which indicates the separation of gelatinous silica. The silica shows no salt cubes so that the probability of the presence of nepheline is very slight. When the hydrochloric acid solution was tested with sulphuric acid gypsum crystals were formed thus proving the presence of lime in the mineral. It is possible that the mineral in question is melilite and that the rock approaches alnöite in its composition.

From the above it will be seen that the rock may be considered as either holocrystalline or as hypocrystalline with a glass which has, through secondary influences, become spherulitic in structure and cryptocrystalline.

A chemical analysis of this rock was made by the Survey, W. A. Noyes, analyst, and gave the following results:—

Analysis of amphibole monchiquite.

SiO_2	43.50
TiO_2	2.10
Al_2O_3	18.06
Fe_2O_3	7.52
FeO	7.64
CaO	13.39
MgO	3.47
K_2O	1.30
Na_2O	2.00
H_2O	1.22
Total	100.20
Specific gravity (Williams)	3.051 at 15° C.

The comparison of its chemical composition with that of other rocks of the monchiquite group is shown on page 111.

The only question of importance which attaches itself to this rock is whether the mineral melilite occurs in it and whether it should be grouped with the alnöites or monchiquites. For the present it is placed with the monchiquite group.

CHAPTER VIII.

Contact Metamorphism and Genetic Relations of the Rocks of Magnet Cove.

I. Contact Rocks.

II. Contact Minerals.

A. Contact Minerals from Quartz and Sandstone.

B. Contact Minerals from the Calcite.

III. Relation of the Igneous Rocks of Magnet Cove to each other and to Adjacent Sedimentary Rocks.

I. CONTACT ROCKS.

As has been stated in the preceding descriptions of rocks from the Magnet Cove region, many varieties of rock occur whose affinities and relationships are very uncertain. These have for the most part been called *hornstones* and have been considered as metamorphosed rocks. Their microscopic physiography is very indefinite and in the majority of cases allows very little to be determined in regard to their origin or present composition. It is seldom that two of these rocks present the same appearance, although a few general characteristics may be detected in almost all of them. In consequence of this latitude in their mineralogic composition and of the infiniteness of their microscopic physiography only a general description of them will be given.

Macroscopically they form dense black or dark bluish or greenish gray rocks which break easily under the hammer and show a conchoidal fracture on the broken surfaces.

They are often filled with cubes of pyrite which vary in size from microscopic individuals up to crystals measuring 8 to 10mm on an edge. On their broken surfaces the rocks often present a somewhat blotched appearance showing that there was a tendency towards a re-arrangement of the molecules forming the rock, but that in most cases the re-arrangement only went far enough to suggest such an alteration in the structure.

Under the microscope sharply defined minerals can seldom be discovered. The rock appears as a confused mass of extremely fine feldspar needles intermixed with much isotropic material and small quantities of choritic substance.

Large quantities of colorless minerals having a high index of refraction and showing a surface in high relief almost always appear. These apparently globular substances show very high interference colors, but their extinction is not very sharp.

Biotite is scattered through the whole rock in the form of small, reddish brown crystals of secondary origin. It appears in small, irregular, strongly pleochroitic flakes, in which the colors change from a reddish brown to a dark chocolate-brown or black. The absorption of light, when the cleavage planes of the mineral are parallel to the plane of the lower nicol, is always very great and in many cases almost total.

Pyrite appears everywhere in the form of small cubes and is often very much altered about the edges; and not infrequently this decomposition has penetrated deep into the the crystal. The crystals then consist of a mass of reddish brown or bright red material which has no action on polarized light and, even between crossed nicols, retains its reddish color showing that limonite and not hematite is present.

Grains of magnetite occur very frequently and are often thickly disseminated among the other minerals of the rock.

Occasionally the outline of a crystal of pyroxene or of amphibole is suggested by grains of magnetite or by flakes of mica arranged along the lines which represent its edges.

Calcite and other decomposition products in many cases make up a large part of the rock.

It appears from the above description that little or nothing can be made out about many of the rocks belonging to this class and hence that any suggestions regarding their relations to the geology of the region are uncertain and unsatisfactory.

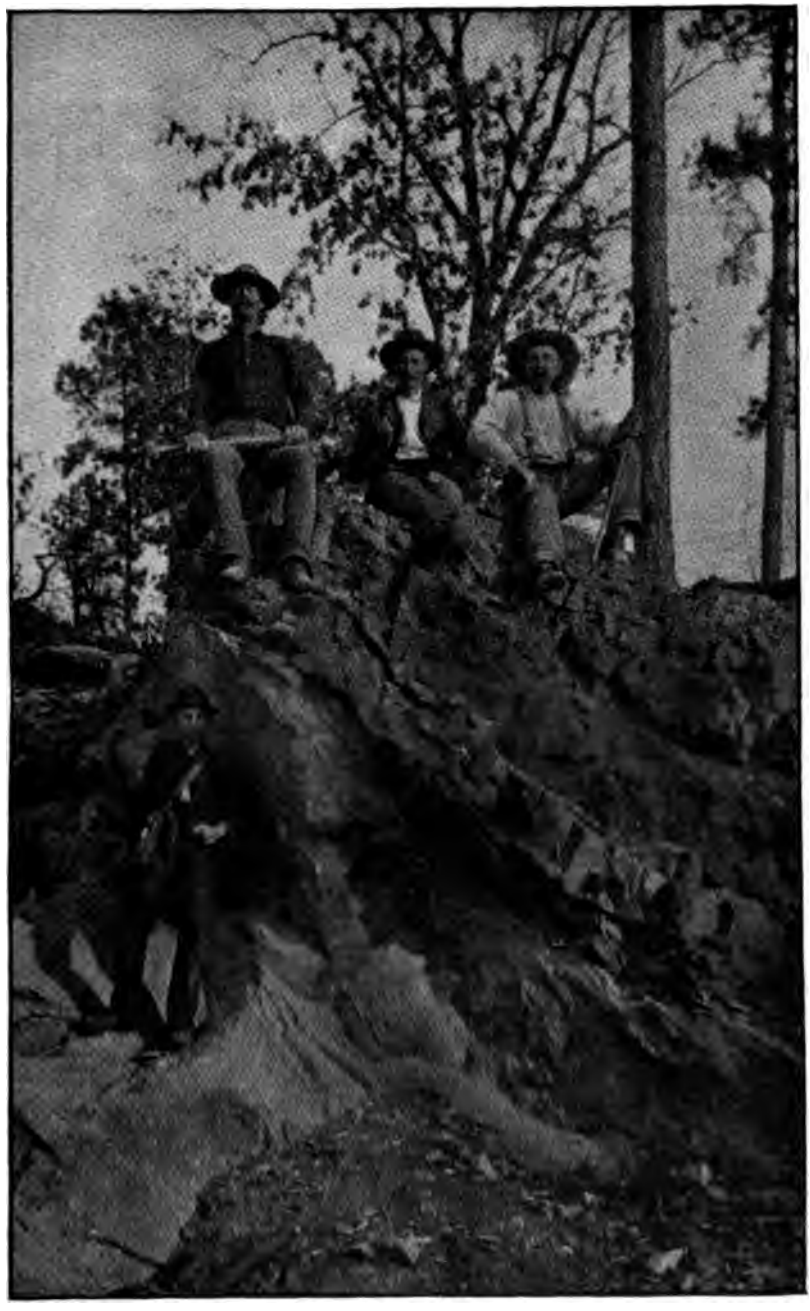
In the case of some of the shales which lie directly in contact with the intruded syenite of the Diamond Jo quarry (see page 197), the metamorphic action of the igneous rock is much more evident. Specimens were taken from this

Fig. 21. *Contact of eleolite syenite dike rock with the Paleozoic rock in Diamond Jo quarry.*

A. Eleolite syenite (Diamond Jo type). *B.* Metamorphosed sedementary rock. (7.7cm).
C. Much altered rock (30 cm). *D.* Slightly altered rock (1m).
E. Unaltered, but contorted shale.

contact at several points (Fig. 21) and studied. The description of the different bands is as follows: (*A*) represents the syenite in which the Diamond Jo quarry is situated and (*B*) is the first contact zone. It is in general about 7.7cm (3 in.) wide, but at one point it extends down into the syenite for twice that distance. It is a close-grained, dense, hornstone-like rock, showing almost no indications of having ever been stratified.

Under the microscope it also appears close-grained and massive and is seen to be filled with an immense number of small, green crystals which belong to the pyroxene group. These have a high index of refraction which makes them appear as if their surfaces were raised above the level of the section. Although of a decidedly green color these grains



CONTACT OF ELEOLITE SYENITE DIKE ROCK WITH PALEOZOIC ROCK.

have little or no pleochroism and in this respect resemble ægirite. Their angle of extinction, where it could be observed, is small. Some sections which are approximately at right angles to the vertical axis show an eight-sided figure with two sets of cleavage cracks lying parallel to the two sets of small faces. These systems of cleavage cracks are approximately at right angles to each other thus giving an additional proof of the pyroxenic character of the mineral. Although this substance has been described in its crystalline form in order to show its relation to the pyroxene group, this is by no means the way in which it most commonly appears. As a rule the individuals classed under this head consist of minute, round grains rarely exceeding 0.05mm in diameter while the crystals just mentioned are seldom much larger, but in a few cases have been observed to be as much as 0.08mm in size. These small grains and crystals are always filled with innumerable minute gas inclusions often showing an exterior crystal form corresponding somewhat to the form of pyroxene. The general habit and microscopic physiography of this mineral show that it is the result of secondary action on the sedimentary rock and is not, as might be supposed, the first crystallization of a quickly cooled syenitic magma.

A large number of small, white or very light yellow grains are scattered among these green crystals. They possess, like the latter, a high index of refraction and exhibit a rounded surface, but are without any distinguishable crystal form. They have high polarization colors, but the extinction is not very sharp, being masked to some extent by the internal reflections due to the high refractive index. It is possible that these crystals are related to titanite, but as no tests have been made to confirm this supposition it can only be put forward as a suggestion based upon the general appearance and characteristic of the mineral and their likeness to those of titanite observed elsewhere.

Biotite exists in this rock as small irregular plates which seldom exceed 1.0mm in their greatest diameter. Like those described in the other metamorphosed rocks of this region they

are very strong in their absorption of light and in their pleochroism. They often occur filling the space and marking out the forms of some other crystals which, from their general appearance, seem to have been large augites.

The question concerning the original conditions under which these decomposed augites were formed immediately presents itself, but, as yet, no satisfactory explanation of their occurrence has been suggested. The rock in which they were found was many feet below the surface of the ground and when it was laid bare by the opening of the quarry some time ago it appeared as a perfectly fresh band of metamorphosed shale. The occurrence of large crystals of augite completely altered into irregularly arranged biotite plates could therefore hardly be ascribed to the action of atmospheric or superficial weathering, but must rather be referred back to the time when the syenite was still hot and the contact rock was permeated by hot saline waters.

The groundmass, if it may be so called, in which these crystals are imbedded consists of a colorless, glassy looking material which, when examined between crossed nicols, is seen to be a double refracting substance. In many cases it appears as if it were filled with lath-like plagioclase crystals which are, however, so confused and distorted by the spheroidal structure that their character is almost indeterminable.

Where the metamorphosed shale comes in direct contact with the syenite large crystals of orthoclase are found extending out from the latter into the sedimentary rock showing that an exchange of substance and a smelting together of the two rocks has taken place. At the ends furthest away from the metamorphosed rock these crystals are comparatively free from inclusion of foreign material, but as they approach nearer to the contact line they gradually become filled, first with minute, dust-like grains of magnetite and then with small, green augitic crystals which become more and more frequent until, at last, the character of the feldspar is entirely lost and the mineral is completely filled with the green crystals as already described.

The next band (*C*) is 30cm (1 foot) wide and consists of a

shale in which, although it has also been much altered, a certain stratification can be observed. A secondary cleavage making a sharp angle with the contact of the syenite and the sedimentary rocks is however much more prominent than the original bedding planes.

(*D.*) consists of a somewhat arenaceous shale in which the cleavage makes equal angles on both sides of a normal to the contact line. So little change was macroscopically visible in this belt that it was deemed unnecessary to examine it microscopically.

(*E.*) is the ordinary shale of the region, but its flat bedding planes have been converted into wavy surfaces by the intrusion of the igneous rocks. All other evidences of metamorphic or contact action are wanting.

Another contact rock which is of interest is that occurring on the hill south of the house marked "J. F. Moore, house" Macroscopically this rock has a light yellowish, often almost pure white color and contains numerous small, black grains disseminated through it. (Page 179.)

It shows on its weathered surface a more or less distinct banding, with an alternation of protruding and receding layers, which give it the appearance of a water-worn shale in which the successive layers were not all of the same hardness.

This rock lies immediately above the eleolite garnet syenite and may be a zone of Paleozoic rock which has been altered by the intrusion of these large masses of igneous rock.

Under the microscope the rock is seen to be made up of a colorless, transparent groundmass through which are disseminated numerous crystals of secondary biotite and magnetite.

The groundmass consists of small (0.1 to 0.2mm) colorless, transparent crystals which are nearly equal in all their dimensions. These crystals are so massed and crowded together that they only occasionally show an idiomorphic form. When, however, such a form appears it is hexagonal and apparently shows a rhombohedral hemimorphism. Thus several cases have

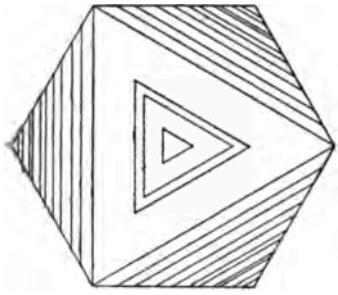


Fig 22. *Crystal of unknown substance in the metamorphosed rock* (×100.)

been observed where the crystal is so situated with its vertical axis perpendicular to the plane of the thin section that a hexagonal outline is apparent and inside of that there are a succession of rhombohedrons so situated that they build up a pyramid about the vertical axis (See fig. 22). By raising and lowering the tube of the microscope the various sections of this pyramid come successively into focus.

The index of refraction and the double refraction of this mineral are both high and the character of the double refraction is negative. The hexagonal sections, observed, above are isotropic. The individuals are so small that but little can be learned about their optic properties.

A chemical analysis was made of the rock by the Survey, W. A. Noyes, analyst, with the following results:—

Analysis of metamorphosed rock.

SiO_2	61.12
TiO_2	0.35
Al_2O_3	20.86
Fe_2O_3	4.22
CaO	0.68
MgO	0 18
K_2O	7.90
Na_2O	3.66
Ignition	0.58
Total	99.55

On account of the small amount of other minerals present this analysis expresses approximately the composition of the mineral constituting the groundmass. The analysis is approximately that of a potash feldspar and it might be supposed that the groundmass consisted of some such mineral did not the optic behavior of the mineral militate against such a conclusion. The identity of this mineral is, for the present, left an open question.

Biotite occurs in small (0.2 to 0.5mm) reddish brown, hexagonal plates and exhibits strong pleochroism.

Magnetite is present in small grains and rods and in a few cases has been altered to hematite.

Minute detailed descriptions of several other contact zones and rocks from various localities might be added, but they would be of little interest or value for, in the main, they are similar to those just described and where other minerals appear their identification is so difficult, on account of the almost complete want of characteristic crystal forms and the impossibility of separating the minerals satisfactorily with any of the heavy liquids, that such a description as could be given would be worthless.

II. CONTACT MINERALS.

Under the head of contact minerals are included some of the most interesting minerals which occur about the Cove and some of those which have raised the most important discussions which have ever occupied the mineralogic world.

The contact minerals are of two classes, namely, (A) those formed on the sandstones and quartz crystals associated with the novaculite rocks and (B) those formed by the metamorphosing of the calcite deposits inside of the Cove.

A. Contact Minerals from Quartz and Sandstone.

Along the belt of coarsely crystalline quartz rock which has been described (p. 192) as lying just west of Magnet Post-Office and extending for a kilometer (0.62 miles) or more in a N. N. W. direction there occur many large quartz crystals whose surfaces are more or less covered with brilliant, black crystals of brookite of all sizes.

The quartz crystals themselves are of many varieties, some being clear and transparent like the so-called Hot Springs crystals or rock crystal. These usually occur attached at one end and are therefore seldom doubly terminated. *Smoky quartz* also occurs in this belt and is often found in very large crystals

weighing in some cases as much as 4 to 5 kilos. (9 to 11 pounds). Fragments of such crystals are also found in great numbers and it is evident that the Indians made use of them, as well as of the novaculite, in the manufacture of their arrow-heads, spear-points, etc. In many cases this smoky quartz is of a very beautiful color and might well be employed in the manufacture of jewelry and *objets de luxe. Milky quartz* is much more common than either of the two varieties just mentioned and crystals of it often occur doubly terminated. The crystals of this variety are usually somewhat smaller than those of either the rock-crystal or the smoky quartz found in the same locality.

The quartz crystals are usually terminated only by the primary prism and pyramid faces and seldom if ever show any other forms. They are generally much corroded on the surface and the spots where brookite crystals were originally implanted are indicated by holes left in the surface of the crystal. It is an interesting fact that these brookite crystals are not found inclosed in the quartz crystals but only implanted on and occasionally imbedded in the surface.

Striations parallel to the horizontal prism-pyramid edges of the quartz crystals appear to be almost if not quite wanting on the specimens from this locality. Compare the statements made in the article by Lewis Feuchtwanger on "The Parallel Striae or indented cross-lines on Rock Crystal" * in which he mentions the rock crystal from Magnet Cove.

Brookite. The brookite which occurs most commonly on the quartz crystals just described is that form which was originally known as arkansite and over which there was so much discussion concerning its composition and crystal form.

It was first described by C. U. Shepard† as one of three new minerals which had been sent to him by the Rev. E. R. Beadle of New Orleans. Shepard gives the accompanying figure (Fig. 23) as representing the crystal form of the mineral and

* Proceedings of the American Association for the Advancement of Science, Vol. XIX., (1870) 1871.

† On three new mineral species from Arkansas, etc. Am. Jour. Sci. Series 2, Vol. II., 1846, p. 249.

describes the angles and the faces as follows: "Primary form. Right rhombic prism. *M* on *M*,* 101°.

Secondary form:—*M* on *c*, 133° 45′.

c on *c* over the edge *x* 135° 15′.

Edge *x* inclines to edge *x* at about 94°. Cleavage indistinct. Surface *M*, brilliant, *c* less so, *d* brilliant, though drusy, and channelled vertically. Fracture sub-conchoidal, to uneven. Lustre metallic. Color dark steel-gray to iron black. Face *c* tarnishes blue, like specular iron. Streak dark ash-gray. The powder (until it becomes perfectly fine) shows points with metallic lustre.

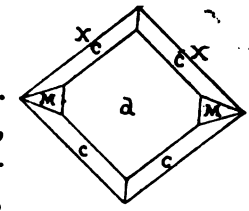


Figure 23. *Brookite (arkansite) (after Shepard).*

Brittle. Hardness 7.0–7.5."

In a foot note Shepard gives a number of chemical reactions obtained from the mineral and comes to the conclusion as far as his investigation and the quantity of material at his disposal would permit, that the mineral consists of a titanate of yttria, in which neither lime, oxide of cerium, iron or manganese are present. He describes the crystals as being about one-fifth of an inch in diameter and as occurring implanted upon quartz crystals, which are attached to a surface of brownish green coccolite. He named the supposed new mineral *arkansite* after the state in which it is found.

In 1847 under the heading of "Further account of the Arkansite"† Shepard describes a crystal which came from Dr. W. B. Powell of Memphis, Tenn., who was the discoverer of the locality and the finder of the specimens which Shephard first obtained from E. R. Beadle. He mentions the occurrence of a new face *a* (Fig. 24) which truncates the acute angles of the primary form, and he states that the angle *M* on *M* is constantly between the values 101° and 101° 15′, while that of *a* on *a* is 128°. He gives the specific gravity as 3.854. He then gives a number of chemical tests and closes by stating

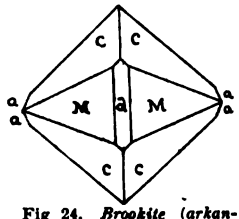


Fig 24. *Brookite (arkansite) (after Shepard.)*

* The lettering originally used by Shepard has been retained.

† Am. Jour. Sci. Series 2, Vol. IV., 1847, p. 729.

it as his opinion that the arkansite is a "niobate of yttria and thorina?" *

In 1849 a number of articles appeared on the subject of arkansite most of which were evidently written without the knowledge of the existence of the others.

August Breithaupt published an article entitled "Mineralogische Beschreibung des Arkansits" † in which he gives the measurements of the angles and calculates an axis ratio for the new mineral. He places the crystal in a different position from that adopted by Shepard and obtains the following faces (Figs. 25 and 26) angles and axis ratio :—

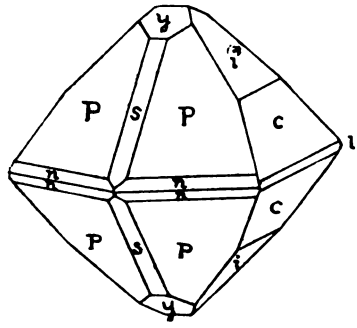


Fig. 25.

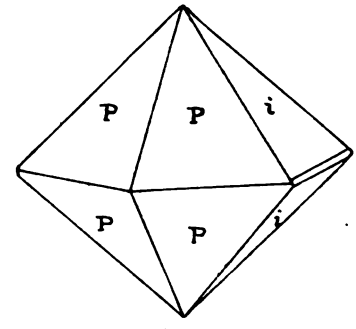


Fig. 26.

Brookite (arkansite) (after Breithaupt.)

$P : P = 135° 15'$ short polar edge; $95° 20'$ long polar edge; $101° 18'$ basal edge.

$y = \frac{1}{2}P\breve{\infty} = 124° 2'$	$i = 2P\breve{\infty} = 79° 41'$
$c = 3P\breve{\infty} = 58° 10'$	$s = P\bar{\infty} = 86° 31'$
$l = \infty P\breve{\infty}$	$n = 2P = 125° 56'$

Axis ratio $a : b : c = 1 : 1.668802 : 0.941023$.

He states that the crystal cannot be made to coincide with brookite.

In July, 1849, a note from W. H. Miller ‡ was published by the editor of the Philosophical Magazine in which it is stated

* In the Jahresbericht über der Fortschritte der reinen, pharm. und technisch Chemie, Physic, Mineralogie und Geologie. Herausgegben von J. Liebig und H. Kopp, 1847-48, there appears on page 1160 a resume of Shepard's two descriptions and a note to the effect that in the volume for 1849 the close relation of this mineral to brookite would be discussed.

† Poggendorfi's Annalen. Band LXXVII., 1849. p. 362.

‡ Phil. Mag. (3) XXXV., 1849, p. 75.

that the arkansite of Magnet Cove, Ark., is crystallographically identical with brookite.

Another paper which was published on this subject at about this time was entitled "Examination of three new mineral species proposed by Prof. C. U. Shepard, by J. D. Whitney" *.

In this article Whitney says that Shepard called the mineral a titanate of yttria and possibly zirconia and thorina and then decided that it was "a niobate of yttria and thorina." Whitney found it to be pure titanic acid with only a trace of iron and redetermined the specific gravity. He also states that it has the crystal form and specific gravity of brookite.

Teschemacher † examined the same crystal that Whitney did and also came to the conclusion that it was brookite. He obtained the following angles:—$M : M = 100°$, $M : c = 133°\ 35'$ $c : c = 135°\ 45'$ $a : a = 124°$ (See Fig. 24 on page 305.)

In the same year C. Rammelsberg published a paper entitled "Ueber die Identität des Arkansits und Brookits in chemischer und krystallographischer Beziehung." ‡ He first shows that Shepard's determination of the chemical composition of the mineral is wrong and that the substance is a pure oxide of titanium, TiO_2. Crystallographically he shows the close coincidence between this new mineral and brookite although the habit of the two minerals is quite different. He next compares the specific gravities of arkansite, brookite and anatase and comes to the conclusion that arkansite is an oxide of titanium which has the crystal form of brookite, but the density of anatase.

Damour and Des Cloizeaux published || some analyses and made a number of specific gravity determinations. The analyses are as follows :—

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* Journal Boston Nat. Hist. Soc., Vol. VI., 1849, p. 42 (original article.)

Notice of same in Am. Jour. Sci., Series 2, Vol. VII., 1849, page 433.

Also Proc. of Boston Soc. Nat. History, Vol. III., 1851, p. 96, (entitled "Analyses of C. U. Shepard's New Minerals.")

† Proc. Boston Soc. Nat. Hist., Vol. II., 1849, p. 132 (original paper) and Am. Jour. Sci. Series 2, Vol. VIII, 1849, p. 274.

‡ Poggendorff's Annalen, Band LXXVII., 1849, p. 586.

‖ Ann. Min. (4) Vol. XV, p. 447. Cited after the Jahresbericht über die Fortschritt der Chemie, etc. Liebig and Kopp, 1849, p. 729.

Analyses of arkansite (Damour and Des Cloizeaux.)

CONSTITUENTS.	a.	b.	c.
TiO_2	99.36	96.72	101.69
Fe_2O_3	1.36		
SiO_2	0.73		
Insol Residue		6.39	1.39
Total	101.45	103.11	103.07

The suggestion is made that some of the titanic acid is present in the form of a lower oxide.

Breithaupt published a second article entitled "Ueber Pleomorphie der Titansaüre," * as an answer to Miller and Rammelsberg and in it he refers to their two articles and in substantiation of his views states that brookite has a cleavage parallel to the prisms making an angle of 104°12′ with each other while arkansite has not. He suggests that there are four varieties of TiO_2, viz:—

Arkansite and brookite—orthorhombic.

Anatase and rutile—tetragonal.

R. Hermann published a paper† in which he states that he has confirmed the previous measurements obtaining the

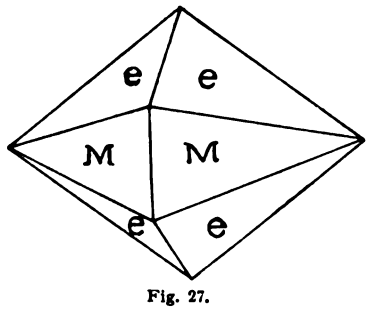


Fig. 27.

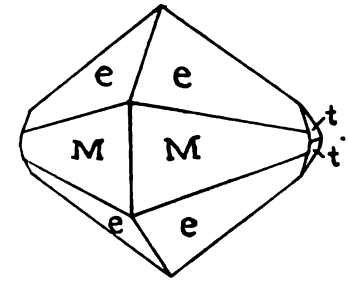


Fig. 28.

Brookite (arkansite) (after Hermann.)

prismatic angle 100°30′, and the octahedral angles 135°30′; 101° and 94°. He gives two drawings of the crystals, Figs. 27 and 28. His analysis afforded:—

* Pogg. Annalen. Band LXXVIII., 1849, p. 143.

† Journal für praktische Chemie, von Erdmann und Werthe, Jahrg. 1850, p. 200; als e Am. Jour. Sci. Series 2, Vol. XI., 1851, p. 229.

Analysis of arkansite (Hermann.)

TiO_2	96.50
Fe_2O_3	1.00
U_2O	Trace.
SiO_2 and gangue	2.50
Total	100.00

Specific gravity 3.79 (much lower than usual, probably due at least in part to impurities—J. F. W.)

In 1876 G. vom Rath published among his "Mineralogische Mittheilungen" an article entitled "Brookit von Atliansk im Ural und Arkansit, umgeändert in Rutil aus Arkansas." * G. vom Rath states that it is probable that the brookite crystals from Magnet Cove come from two distinct localities because he finds two varieties which are quite different from each other. The first variety he designates as (*A*) and describes them as black, unaltered brookite which is proved to be such by its specific gravity. The second variety (*B*) consists of 'blackish or reddish brown,' altered crystals possessing a peculiar glistening surface and the specific gravity of rutile.

The crystals (*A*), which range from 3 to 15mm in size are bounded by the faces, $e=P\breve{2}$ (122), $M=\infty P$(110), $z=\frac{1}{2}P$(112), $t=2P\breve{\infty}$ (021).†

The face *e* often predominates to such an extent that *z* is either wanting or appears only as a bevelment of the brachydiagonal polar edges of *e*, and *M* and *t* appear only as

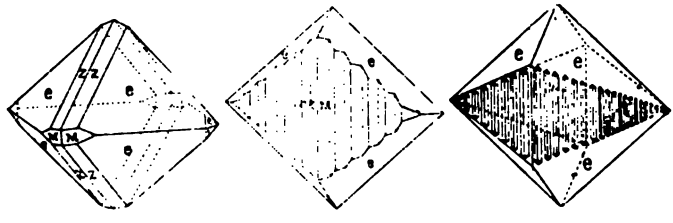


Fig. 29. Fig. 30. Fig. 31.

Brookite from Magnet Cove (after vom Rath.)

* Poggendorff's Annalen, Band CLVIII., 1876, p. 407, with a supplement in the N Jahrb. f. Mineralogie Jahrgang, 1876, p. 397.

† The Miller nomenclature is not given in the original article, but is replaced by that of Weiss.

subordinate faces beveling the corners (See Fig. 29). Sometimes the faces *M* and *e* are equally developed and the apparently dihexahedral form of the arkansite crystals (Fig. 31) is formed. Again the crystals have the appearance of that shown in fig. 30 and consist of a combination of *e* and the macropinacoid. The latter face is, however, not a simple face, but is made up of a frequent alternation of the prism faces. G. vom Rath determined the specific gravity for the crystals (*A*) with the brilliant surfaces as follows:—3.807, 3.962 and 4.074.

The crystals (*B*) occasionally attain a length of 40mm and are usually in the form of the apparent dihexahedron. In some cases they are bounded by the faces *z* (112) and *M* (110) (See fig. 32) a combination which has not previously been observed. This form is somwhat similar to that of rutile and these crystals have often been mistaken for that mineral. The angles, which on account of the peculiarly glimmering surface of the crystal can only be measured with a contact goniometer, are those of brookite. Besides the already mentioned peculiarities of the crystals (*B*) vom Rath mentions and describes the peculiar *moiré metalique* lustre which is so characteristic of them. He states that the surface, as shown in fig. 32, is due to numberless, minute rutile crystals which cover the surface of the crystal. At the same time the interior of the crystal is found to be replaced by red, rutile crystals and the whole arkansite crystal has become a paramorph of rutile after brookite.

Fig. 32. *Brookite from Magnet Cove (after vom Rath.)*

G vom Rath determined the specific gravity of some of these paramorphs with the following results:—

Sp. gr.=4.148, 4.193, 4.199 and 4.212.

It is evident that these values are those of rutile.

Occasionally the rutile crystals making up these paramorphs are so small that their forms cannot be determined,

but usually the forms P (111), ∞P (110), $\infty P\infty$(100), $P\infty$ (101), and $\infty P_{\frac{3}{2}}^{3}$ (320) are easily distinguished and the positions of the crystals determined. A 20mm dihexahedral crystal of arkansite which was altered to rutile crystals 5mm in length was found by vom Rath with the original American label reading "Arkansite with an habit of Rutil". He remarks that the alteration is not only superficial, but is a complete transformation in the substance of the crystal.

It is seen from the above description that the rutile crystals form parallel aggregtions and, what is more remarkable, that the latter arrange themselves in certain positions with regard to the brookite crystals which they replace. On the face M the rutile prisms are vertical and are so situated that a prism of the second order (100) would coincide with the macropinacoid (100) of the brookite. This is shown diagrammatically in fig. 31. Another arrangement is that where the small rutile prisms lie at right angles to the brachydiagonal edges of the pyramids e.* G vom Rath then remarks on the fact that the paramorphosed arkansite crystals, if the paramorphism is left out of the question, might easily be mistaken for twin crystals of rutile and he goes on to show from a crystallographic standpoint how this occurs.

G. vom Rath closes his article with the remark that this transformation of brookite into rutile presents a new example of two forms of one and the same substance, which both occur in the shape of one of them. This shape was left by the earlier form as a proof of its previous existence while the other form now exists filling the space originally occupied by the former.

In 1886 S. L. Penfield published an article entitled "Brookite from Magnet Cove, Arkansas,"† in which he gives the measurements and description of some fine brookites from the collections of Professor G. J. Brush and Yale College. He states that but little has been published in American journals upon the subject of this mineral and that nothing can be said in regard to its geologic relations.

* Further notes on this subject appear in N. Jahrb. f. Min., Jahrg., 1876, p. 397.

† Am. Jour. Sci. Series 3, Vol. XXXI., 1886, p. 387.

The forms which Penfield observed are as follows:—

$e=P\breve{2}$ (122)	$a=\infty P\bar{\infty}$ (100)
$z=\frac{1}{2}P$ (112)	$m=\infty P$ (110)
$\chi=\frac{1}{2}P\breve{2}$ (124)	$t=2P\bar{\infty}$ (021)

Penfield writes regarding these faces:—

"Of these forms, *e* is the most common, occurring frequently alone, usually, however, in combination with *m*. This latter combination is especially interesting when the prism is of such a size that it meets the four planes of the pyramid at the extremity of the *b* axis, forming there a solid angle of six faces; (Fig. 17, pl. 20).* This combination is very common and appears like a doubly terminated hexagonal pyramid. The brachydiagonal pole edge of *e* is inclined 60° 45′ to the vertical axis, so that the projection of the six faces upon the brachypinacoid would be almost a perfect hexagon. As a rule, the faces of the prism vary in lustre from the pyramid and the frequent truncation of the vertical edge of *m* by the macropinacoid *a* serves as a ready means of orientation. The next most frequently occurring pyramid is *z*, which usually occurs beveling the branchydiagonal pole edge of *e*; fig. 21, pl. 20 showing also the prism *m*, a very common combination. The brachydome *t* is not so common as the above mentioned forms and usually appears with very small faces. One hand specimen of a very much decomposed siliceous rock contained a great number of small lustrous crystals about 2mm in diameter, which show a very large development of *t*, (fig. 19, pl. 20) but I have seen no large crystals with this habit. The macropinacoid *a*, appears very frequently, but seldom largely developed.

"The crystal which first attracted my attention is about 7mm in its greatest diameter with very lustrous faces and symmetrical development; it is only a fragment. It shows all of the forms mentioned above with the addition of χ, which bevels the macrodiagonal pole edge of *z*. χ is a rare pyramid in this

* The figures drawn by Penfield are identical with some of those published later by Dana and hence Penfield's figure numbers are altered to refer to Dana's figures on plates 19 and 20 of this report.

species, and was first identified by von Leuchtenberg (Materialien zur Mineralogie Russlands, VI., 204) on crystals from the Urals. The planes are arranged as in fig. 14,* plate 20. It will be noticed that the prominent pyramid is here z, while e is very subordinate. I have been able to find no duplicate of this crystal. Except the large round crystals which are wholly changed into rutile and which have the habit shown in fig. 14, pl. 20, only with more prominent prismatic development; all that I have seen show the pyramid e largely developed. The two pyramids z and e might be mistaken for one another were it not for the prism m which serves for orientation.

"The angles which were measured and served for the identification of the faces (on crystal shown in fig. 14, pl. 20) are given in the following table, together with the corresponding angles taken from Kokscharow.

			Kokscharow.
$e : e$	122 : $\bar{1}22$	44° 19½′	44° 23′
$z : z$	112 : $\bar{1}12$	53 37	53 48
	$11\bar{2}$: $\bar{1}1\bar{2}$	53 42	53 48
	112 : $1\bar{1}2$	44 30	44 46
$\chi : \chi$	124 : $\bar{1}24$	28 39	28 28
	$12\bar{4}$: $\bar{1}2\bar{4}$	28 41	28 28
$e : z$	122 : 112	17 3½	17 6
$m : m$	110 : $1\bar{1}0$	80 6	80 10
	110 : $\bar{1}10$	99 51½	99 50
$a : m$	100 : 110	40 4	40 5
$m : z$	110 : 112	53 40	53 45
	110 : $11\bar{2}$	53 40	53 45
$m : t$	110 : 021	55 18	55 19
	$\bar{1}10$: 021	55 19½	55 19

It will be noticed that the angles agree closely with those given by Kokscharow, and a consideration of those angles calculated to determine the monoclinic symmetry of the crystal, i. e., $m : z$ and $m : t$ give us no sufficient ground for assuming that

* Figure 14, plate 20, differs from Penfield's figure 4 only in the size of the faces z and χ. In Penfield's figure χ is long and narrow while z is wide and intersects the face e in an edge.

the crystallization is other than orthorhombic. The reflections from the faces of these crystals are usually not very sharp; those from the one shown in fig. 14, pl. 20 are, however, an exception. In this crystal vicinal faces lay in the prismatic zone making an angle of 0° 39′ with *m*, and with the front edge of the vicinal prism measuring 81° 22′. There is also a vicinal pyramid inclined 0° 21′ to *z*, and in the zone *z*, *e*, the vicinal faces being nearest to *e* and showing faint though distinct reflections.

"The gravity of this crystal taken very carefully is 4.084."

Later in the same year Edward S. Dana published an article* entitled "On the Brookite from Magnet Cove, Arkansas" in which he describes and figures a large number of beautiful crystals from the collection of Mr. Clarence S. Bement of Philadelphia, Pa. In order to make the paper as complete as possible Dana figures a large number of combinations both of the older well known forms and of the new ones about to be described. These are shown in the two plates subjoined, the electrotypes for which were kindly loaned to the Survey by Professor Dana.

Dana determined the following planes on the crystals :—

Pinacoids, $a=\infty P\bar{\infty}$ (100), $c=0P$ (001); prisms, $l=\infty P\bar{2}$ (210), $m=\infty P$ (110), $\varphi=\infty P\bar{3}$ (120) new; brachydome $t=2P\check{\infty}$ (021); pyramids, $z=\frac{1}{2}P$ (112), $\chi=P\bar{3}$ (124), $Q=\frac{3}{4}P\frac{3}{2}$ (234), $e=P\bar{2}$ (122.)

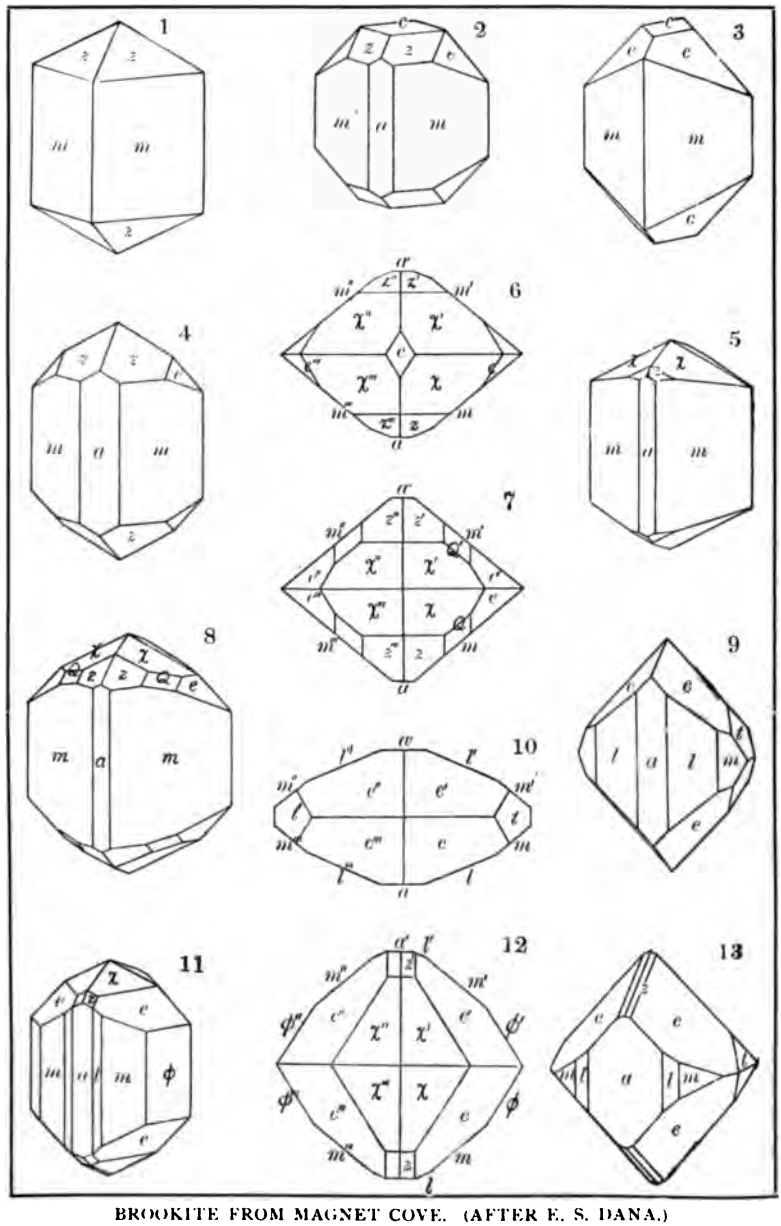
The remainder of the paper has been copied verbatim from Dana with only a few changes to make the nomenclature correspond to that used in other parts of this report.

Dana describes the individual crystals as follows :—

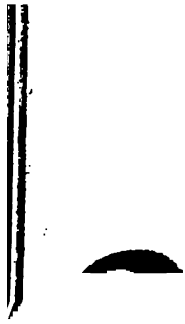
"The crystals may be roughly divided into those of prismatic, and others of pyramidal habit. In the former, figures 1 to 12, with also figs. 14, 15, 16, 18, (Plates 19 and 20,) the fundamental prism, *m*, usually predominates; the forms vary much, however, according to the pyramid by which they are terminated. Figure 1, pl. 19, is a common form, occuring in crystals of relatively large size, sometimes 1 to 2 inches in length; here the pyramid *z* (112)† is alone present. This form, though so

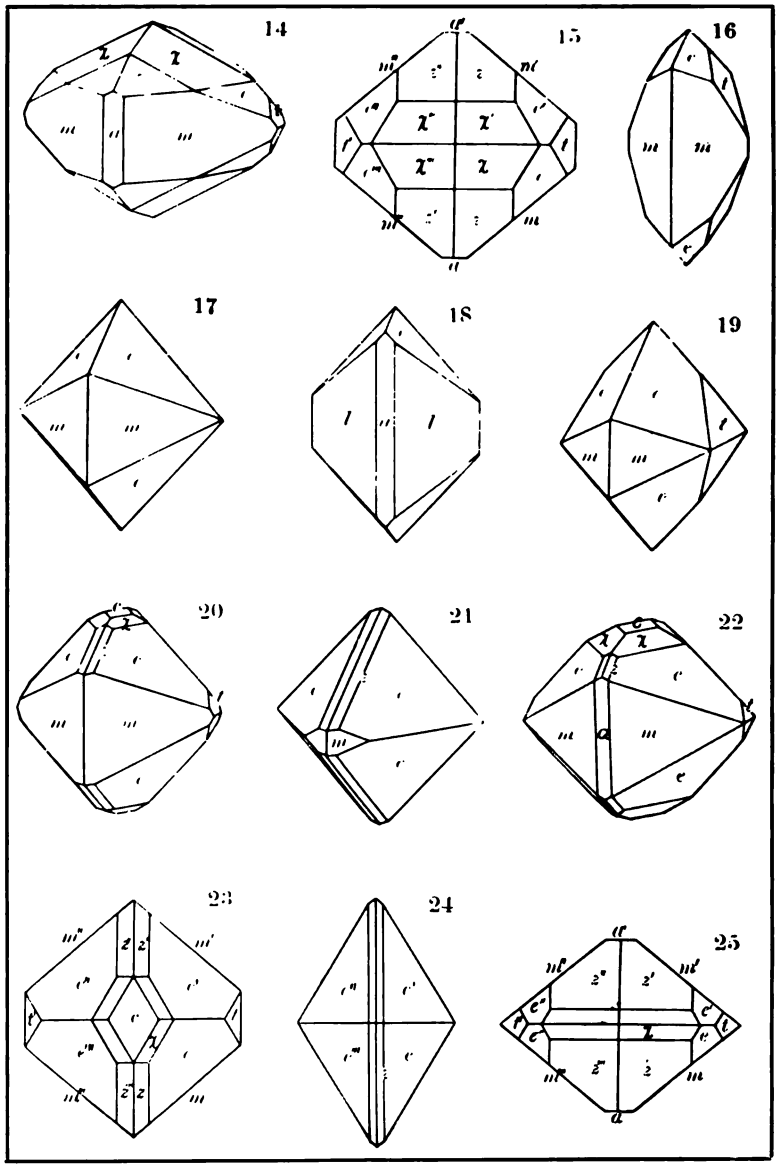
* Am. Jour. Sci., Series 3, Vol. XXXII, 1886, p. 314.

† Dana's abbreviation of the Naumann symbols are omitted.



BROOKITE FROM MAGNET COVE. (AFTER E. S. DANA.)





BROOKITE FROM MAGNET COVE. (AFTER E. S. DANA.)

simple, is interesting because of the similarity it bears to a common form of rutile, the allied species, also TiO_2 in composition. This resemblance is apparent at once, as was remarked by vom Rath, and is in a measure borne out by the angles of the two species. In rutile the prism is one of 90° and the pyramid *s* (111) is a tetragonal pyramid with a terminal angle of 56° 22½′; in this related orthorhombic form the prismatic angle of 80° 10′ and 99° 50′ and the pyramid *z* has terminal angles of 53° 48′ and 44° 46′, calculated from the measurements by von Kokscharow on the usual assumption that the species is orthorhombic. It is interesting to note that this type of crystal is the one which most frequently shows the paramorphic change to rutile. Figure 4, pl. 19, represents a form much like that just alluded to but showing also the common brachypyramid *e* (112) which by some authors is made the unit pyramid. Figures 2 and 3, pl. 19, show other crystals much smaller, and marked by the presence of the basal pinacoid. The crystals, represented in figures 5 to 8, pl. 19, were small, about ⅓ to ½ inch in length, and of a rich reddish brown color, different from the common color of the crystals of the locality, which is deep black. The pyramid which predominates here, sometimes to the obliteration of other terminal faces, is the obtuse brachy-pyramid χ (124) with terminal angles of 48° 54′=$\chi\chi'''$ (124 : $\bar{1}24$) and 28° 28′=$\chi\chi'$ (124 : $\bar{1}24$.) The planes *z* and χ are often striated deeply, parallel to their mutual intersections, and the oscillatory combination of these planes is sometimes so marked that the termination appears to be made by two brachydomes. Figure 6, pl. 19, is a basal projection of a crystal near that shown in fig 5, pl. 19 but having also the planes *c* and *e*.

"The crystal drawn in figs. 7 and 8, pl. 19, is interesting as showing the rare plane *Q* (234) in the zones *z*, *e* and χ, *m*. This plane has not been observed before at this locality, and has only been noted by Groth and Bücking (Mineralien-Sammlung, Strassburg, p. 110, 1878) on a crystal from the Maderanerthal. Figure 16, pl. 20, shows another prismatic form with an acute termination formed by the dome *t* and the pyramid *e*. Figures 14 and 15, pl. 20, represents a short prismatic form of unusual

complexity; fig. 25, pl. 20, (after Penfield) is a basal projection of an allied form, but one in which the pyramid χ is a narrow bevelment of the brachy-diagonal terminal edge of z, much as z bevels the macro-edge of e.

"Figures 11 and 12, pl. 19, represent a rare type of form in which with the unit prism we have also the prisms l (210) and φ (120). This last plane is a new one for the species; it was determined by the measured angles:

$\varphi\ \varphi' = 120 : \bar{1}20 = 62°\ 1' : 61°\ 26'$ calculated (Kokscharow). In figures 9 and 10, pl. 19, a common type of crystal is represented in which the macro-prism l predominates. These crystals are often quite flat parallel to the macropinacoid from the oscillatory combination of the two prisms l and m, and the termination is often formed by narrow faces of the pyramid e. In fig. 18, pl. 20, the prism l is alone and the appearance of the crystal is strongly in contrast to the stout nearly square prism of figs. 1, 2, etc., pl. 19.

"The remainder of the crystal figured are essentially pyramidal in type. The most interesting of these is figure 17, pl. 20, in which the planes m and e are "in equilibrium" and thus form a nearly regular hexagonal pyramid. This is one of most common and striking types occuring at the locality; many of the crystals occurring implanted upon massive quartz have this habit. The front edge of the prism m is not infrequently truncated by the macropinacoid a, and sometimes the planes c, x, χ and t are also present as shown in figs. 20, 22, 23, pl. 20,: these more complex forms still preserve the hexagonal aspect by the predomination of e and m. Fig. 19, pl. 20, is a form, observed by Penfield, of small crystals implanted thickly on a porous siliceous gangue.

"In fig. 21, pl. 20, a form is shown in which the pyramid e predominates, only modified by z and m; in fig. 24, pl. 20, m is absent and only the pyramid e present with its front edge beveled by z. The ordinary projection, used in fig. 21, pl. 20, fails to give the true effect of this type, which is that of an acute nearly square pyramid, elongated in the direction of the $\breve{a}$ axis. The shape is better exhibited in the basal projection of fig. 24,

pl. 20. This form is interesting in the same way as fig. 1, pl. 19, in that it approximates in form and angle to the common acute octahedron of the third form of titanium dioxide, octahedrite. The pyramidal angles of the latter species are 82° 9′, 82° 9′ and 43° 24′ (basal), while the corresponding angles of brookite are 84° 38′, 78° 57′ and 44° 23′. This type of crystal is often altered to rutile. It may be added that the crystal figured in 24, pl. 20, was most strikingly like the pseudomorphs of wolfram after scheelite from Monroe, Connecticut.

"As has been remarked by Penfield, the brookite from Magnet Cove is ill adapted for close measurements. Many of the planes are straited, as those, of the prismatic zone, and those of the zone z, χ, χ', z'. Even when the planes are seemingly smooth they give uncertain or multiple reflections. The following measurements obtained from the best of the crystals under examination, are however, worth recording, though not deserving of great weight.

			Measured.	Calculated (Kokscharow).
$\chi\chi'$	$124 : \bar{1}24$	=	28° 46′	28° 28′
$\chi''\chi'''$	$124 : \bar{1}\bar{2}4$	=	28° 31′	
$\chi\chi''$	$124 : 1\bar{2}4$	=	48° 44′	48° 54′
$\chi'\chi'''$	$\bar{1}24 : \bar{1}\bar{2}4$	=	48° 55′	
zz'	$112 : \bar{1}12$	=	53° 47′	53° 48′
$z''z'''$	$112 : \bar{1}\bar{1}2$	=	53° 44′	
zz''	$112 : 1\bar{1}2$	=	44° 45′	44° 46′
$z'z'''$	$\bar{1}12 : \bar{1}\bar{1}2$	=	44° 46′	
mm'''	$110 : 1\bar{1}0$	=	79° 25′	80° 10′

"A comparison of these angles and those obtained by Penfield show a considerable variation among themselves; while on the whole they correspond tolerably well with the measurements by Kokscharów of Russian crystals."

The latest contribution to a knowledge of the brookite and rutile from Magnet Cove consists of an article by Max Bauer entitled "Ueber die Paramorphosen von Rutil nach Brookit von Magnet Cove, Arkansas". *

* Beiträge zur Mineralogie, VII. Reihe (No. 14). Neues Jahrb. f. Mineral., Jahrgang, 1891, Band, I., pp. 217-232.

Bauer was led to undertake this investigation by the desire to follow further the question whether or not there exist in nature true paramorphs, that is crystals which have simply changed their crystal form by a re-arrangement of the molecules without changing their substance in any way. He had already studied the pseudomorphs of calcite after aragonite from Klein-Sachsenheim* and the pseudomorphs of aragonite after calcite from Sweden† and in both cases had shown that something more than a simple molecular re-arrangement had taken place. He then decided to investigate the crystals of rutile in the form of brookite from Magnet Cove, which had been described by G. vom Rath.‡

The first investigations were made on the rutile-like Brookite crystals originally described by vom Rath § and E. S. Dana||. These crystals are bounded by the faces $M = \infty P(110)$ and $z = \frac{1}{2}P(112)$ and according to the measurement of the angles they are undoubtedly of the brookite form. G. vom Rath found the specific gravity of these crystals to be that of rutile.

Bauer redetermined one of vom Rath's weighings and found it perfectly correct. He compares vom Rath's several determinations of the specific gravity of these pseudomorphs with the values of brookite, arkansite, rutile and nigrine given in Websky's table¶ and remarks that the values found for the in mineral question are appreciably higher than those of unaltered brookite and approach the values given for rutile. He adds, however, that these results alone have but little significance since some specimens of brookite show values higher than those found for the pseudomorphs and that the variations are probably due in a great measure to the amount of ferric oxide contained in the mineral.

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* Neues Jahrb. f. Mineral., Jahrgang. 1886, Band I., p. 62.

† Neues Jahrb. f. Mineral., Jahrgang, 1890, Band I., p. 12.

‡ Poggendorff's Annalen, Band CLVIII, 1876, p 407; etc., (See p. 309 of this report).

§ Pogg. Ann., l. c., (Plate V., Fig. 4.) (Fig. 32, p. 310 of this report.)

|| Am. Jour. Sci., Series 3, Vol. XXXII., 1886, p. 314. Plate VIII., Fig. 1. (Plate 19., fig. 1 of this report.)

¶ Die Mineralspecies nach den für das specifische Gewicht derselben angenommenen und gefundenen Werthen. Breslau, 1868.

In order to determine whether, notwithstanding the high specific gravity, brookite substance and not rutile was present. Bauer made a microscopic investigation of a thin section of one of these pseudomorphs. The crystal which he examined was bounded by the faces already mentioned and, in addition to these, by the faces $\chi=\frac{1}{2}P\breve{2}$ (124). The crystal was shown by a contact gonimeter to have the brookite form and its specific gravity (4.231) was found to be even greater than that determined by vom Rath. A thin section was cut at right angles to the prism edge *M*:*M*. The section has a reddish yellow-brown color and is almost without dichroism. The structure is not uniform over the whole surface. In some parts a distinct cleavage is observed which over large areas possesses a certain direction, but this orientation is not the same in all the areas. Two sets of cleavage-cracks at right angles to each other appear over large surfaces and cover the larger part of the section; in other parts of the section two equally distinct systems of cleavage-cracks appear which are not perpendicular to each other, while in other, smaller and less numerous areas only one system of sharp, parallel cracks occurs. Lastly, other areas of small size occur in which the parallel cleavage does not appear, but is replaced by a number of irregular cracks. These different areas are all sharply separated from each other.

A number of wide clefts appear among the fine cleavage-cracks and have the same directions, but only in rare cases do they reach the edge of the section. They, like the fine cleavage-cracks, are certainly not the result of the cutting of the section, but were present in the crystal previous to that operation, otherwise they would reach to the edge. The areas without the cleavage-cracks form a complete skeleton which only at one point comes to the edge of the section (this probably indicates the point of attachment of the crystal) and is everywhere else surrounded by the portions containing cleavage-cracks and those without show the surface appearance of substances with a high index of refraction.

In parallel polarized light the parts without cleavage-

cracks have virtually a uniform extinction and show the optic characteristics of an anisotropic body.

The portions in which cleavage cracks appear act differently according to the orientation of those cracks. Thus the areas with the single system of cracks and those with the oblique angled, double system act similarly to the portions just described, while the areas with the right angled systems, which are more common than all the rest together, show the optic characteristics of an isotropic substance. If this be examined in convergent polarized light a black cross with very close rings is observed. In the other portions of the section no interference figure appears.

There is little doubt but that the brownish red, uniaxial substance with a high index of refraction, strong, negative double refraction, and slight dichroism, which has two systems of cleavage-cracks at right angles to each other, is rutile, while the portions of the crystal without cleavage-cracks, and which give no interference figure, consist of the brookite which gives the form of the whole crystal.

The way in which these two minerals are arranged in regard to each other shows that the rutile has formed from the brookite and principally by a change of substance from the outside toward the interior. The only point where the brookite substance appears on the outside is at the point of attachment. The alteration appears also to have taken place in a small degree from the inside.

It seems probable, as far as it is possible to judge without chemical analyses, that the alteration has proceeded without any chemical change. A chemical change could hardly consist in anything else than a separation or perhaps an absorption of Fe_2O_3. Blum* assumed that in such a change Fe_2O_3 is separated and forms brown iron ochre in the holes of the crystals whose transversely broken surfaces he examined. Such iron ochre does not appear in the crystals examined by Bauer and he states that if the almost completely similar color of the secondary

* Pseudomorphosen, 4, Nachtrag, 1875, p. 169.

rutile and original brookite can be considered as an indication of an approximately equal amount of iron in the two crystals, there is nothing whatever to suggest a change in the chemical constitution of the crystals and the pseudomorphs must be considered as paramorphs of rutile after brookite.

The fine cleavage-cracks and wider clefts in the rutile portion of crystals add strength to this conclusion, for the rutile is specifically heavier than the brookite and consequently a given quantity of TiO_2 occupies less space in the form of rutile than in the form of brookite. When, therefore, a given space is occupied by brookite material and it changes to rutile cracks and cavities must appear.

The rutile crystals formed by the re-arrangement of the molecules of the brookite have not the same orientation throughout the whole mass although they are often found to be similarly orientated over considerable areas. Thus the greater number of the secondary rutile crystals have their principal axes parallel to the vertical axis of the original brookite. Another portion of the rutile crystals cut the prism faces of the brookite at an angle and produce the *moiré lustre* described by vom Rath. In the same manner the large mass of rutile crystals parallel to the vertical axis produce a similar lustre upon the pyramidal faces of the brookite. The secondary rutile crystals are bounded on the outside by regular faces which make very small angles with the brookite faces. A slight turning of the crystal, therefore, produces first a reflection from the faces of the rutile and then from those of the brookite and gives rise to the *moiré lustre*.

Bauer states that he was unable to find any definite relation between the position of the inclined rutile needles and the elements of the brookite crystals, but thinks it possible that such a relation might be established by examining a larger quantity of material than he had at his disposal.

There occur at Magnet Cove, according to Bauer, two varieties of brookite; first the black arkansites in comparatively small crystals bounded by the faces $M=\infty P$ (110) and e $P\bar{2}$ (122). These are all fresh and unaltered. Second the reddish brown brookite crystals with the rutile-like forms which are all

more or less completely altered into rutile. Bauer remarks that E. S. Dana states that the rutile-like forms, and also the anatase-like forms (fig. 24, plate 20) are commonly altered to rutile, and adds that all those of the latter form that he has seen are entirely unaltered. Bauer states that the reddish brown brookite crystals are much more commonly altered to rutile than the black arkansite and suggests that this may be due to the greater amount of iron contained in the first.*

Through what agencies the alteration of brookite to rutile has been effected Bauer writes that he is not in a position to state nor even conjecture and that, although according to G. Rose's investigations brookite is known to pass into rutile by being raised to a red heat, such a process could not possibly have taken place in this case.

As is seen from the foregoing papers while little is left to be described as regards the chemical or crystallographic constitution of this mineral, but very little is known about its occurrence and geologic relations. The writer has consequently taken especial pains to examine the matter as fully as possible and with the following results.

As has been stated the brookite crystals are found only upon quartz and sandstones of the region included within the Cove proper or the belt immediately adjoining it near Magnet Post-office, or lying loose in the soil where they have been left by the disintegration of the sandstone. Inside the Cove they are found around the whole ring beginning near D. R. Rutherford's house No. 2, at which point the paramorphs of rutile after brookite are most common and appearing again south of the north ridge. South of Thomas Holt's house near the road leading south along the ridge, brookite is found in beautiful, red, semi-transparent crystals implanted on the surface of a semi-decomposed sandstone which, according to Mr. L. S. Griswold of the Survey, overlies the novaculite.

A very perfect red crystal about 7mm long from this locality was sent to the writer by W. J. Kimzey of Magnet Cove

* Beyond this point Bauer's paper becomes a discussion of peculiar forms of twin rutile crystals and the substance of it is given under the head of rutile. (See page 325.) The paper closes with the next sentence of the text.

and upon close examination it was found that the surface of the sandstone upon which the crystal occurs is coated with a complete network of minute tabular feldspar crystals which never exceed 0.2mm in their greatest dimensions. These were tested chemically as completely as the small quantity of material at hand would permit and the results indicate that some member of the plagioclase series is present since both sodium and lime, but not potassium were detected. Again on the south and east sides of the Cove brookites occur scattered among the decomposition products of the syenite. It is evident, however, from the preceding considerations that these have been left by the decomposition of the sandstone on which they were formed and do not belong to the syenitic rocks.

Those brookites which occur implanted on the quartz crystals and are found south of Magnet Post-office are the least perfectly formed crystals of all those found about the Cove and it was to them that Shepard referred when he spoke of the *d* face (orthopinacoid (100) made up of prisms (110)) as being "brilliant, through drusy, and channelled vertically". In many cases these drusy faces have been developed to such an extent that the crystals consist only of thin plates parallel to the orthopinacoid (100) terminated by extremely narrow pyramid faces. Some peculiar conditions of growth seem to have confined this form to the quartz crystals and to have made them either extremely rare or altogether wanting elsewhere.

The question regarding the formation of these crystals is by no means an easy one. That they are directly referable to the metamorphic action of the syenite is beyond a doubt since nowhere else in this extensive series of sedimentary rocks have any such crystals been found.

The novaculites and overlying sandstones as far as they have been investigated are either perfectly free from titanic acid or else contain it only in small quantities. The syenite must therefore be regarded as the source of the titanium from which the brookites were formed. The most plausible theory to account for the transformation of this element from its original condition as titanite, ilmenite or leucoxene in the syenite to that of brook-

ite and, as will be seen presently, to rutile and menaccanite as well, is that it was dissolved by the hot water and steam under pressure while the latter were in contact with the syenite and was recrystallized, not in its old form but as pure titanic acid, when it reached the sandstone and quartz crystals. The titanium oxides may perhaps be considered as having been directly volatilized at the time of the intrusion of the syenite and to have condensed as the dioxide directly or else they may have been volatilized as the chloride of titantium and have been broken up on contact with the air and have formed the dioxide where it is now found.

Rutile occurs in several places about the Cove and, although not nearly so widely distributed as the brookite, very often accompanies it. Thus at the southwestern corner of the Cove, on what has already been mentioned as Perofskite Hill, the crys- of rutile are still quite common and were formerly exceedingly plentiful. At the southeast corner of the Cove at the brookite locality southeast of the house marked R. C. Preston, No. 1 the rutiles are not at all uncommon.

The crystals very seldom appear as single individuals, but are almost always found as twins according to some one of the various twinning laws.

The first mentioned made of rutile twins and, as far as is known to the writer, of the occurrence of this mineral itself at Magnet Cove was made by Fr. Hessenberg * in 1864. Hessenberg described multiple twins in which both the laws, composition face $P\infty$ (101) and composition face $3P\infty$ (301) were combined in the same crystal.

Some of the most interesting forms of rutile which occur in Magnet Cove are the world-renowned sixlings and eightlings. The latter were first described and figured by G. vom Rath.†

One of the most common twinning laws observed in the

* Mineral Notizen, No. 5. Abhandlungen von d. Senkenberg naturf. Gesell. zu Frankfurt, Band IV., p. 205.

This article was not accessible to the writer and the note of it is taken from Dana's mention of his work (Descriptive Mineralogy, by J. D. Dana, Fifth Edition, 1868, p. 160) and Bauer's reference to it in his recent paper (N. Jahrb. f. Mineral., Jahrgang 1891, Band I., p. 230.)

† Zeitschrift für Krystallographie, Band I., 1877, p. 15.

crystals from Magnet Cove is that in which the pyramids of the second order are the twinning planes. When a number of such crystals grow together to form a cyclic twin as is well shown by G. H. Williams in his Elements of Crystallography * the growth may be effected it two ways:—first by the use of *opposite* faces of the pyramid, (011) and (0$\bar{1}$1), as the twinning planes, thus forming a cyclic twin in which the vertical axes of the individual crystals all lie in the same plane forming such a sixling as that

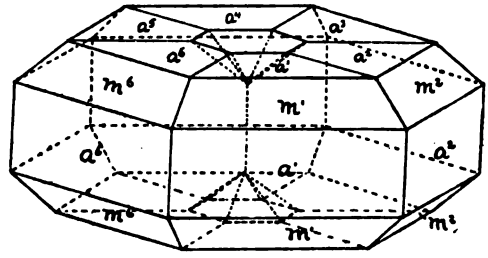


Fig. 33. *Sixling of rutile from Magnet Cove.* Scale=4:1.

represented (Fig. 33); second by the use of *contiguous* faces of the same pyramid (011) (101) alternately as the twinning planes, thus forming a cyclic twin in which the vertical axes form a zigzag, and in which eight individuals are necessary to complete the cycle (Fig. 34). Specimens of both of these varie-

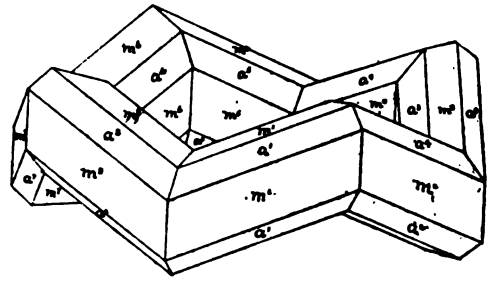


Fig. 34. *Eighting of rutile from Magnet Cove.* Scale—3:1.

ties are not uncommon at Magnet Cove and in some cases the degree of perfection with which the cycle has been completed is very remarkable. Specimens of the second variety have been found in which both the exterior and interior faces were present and the small hole through the center was as sharply bounded as if the crystal had been artificially cut.

* Elements of Crystallography by G. H. Williams, New York, (Henry Holt) 1890, p. 198.

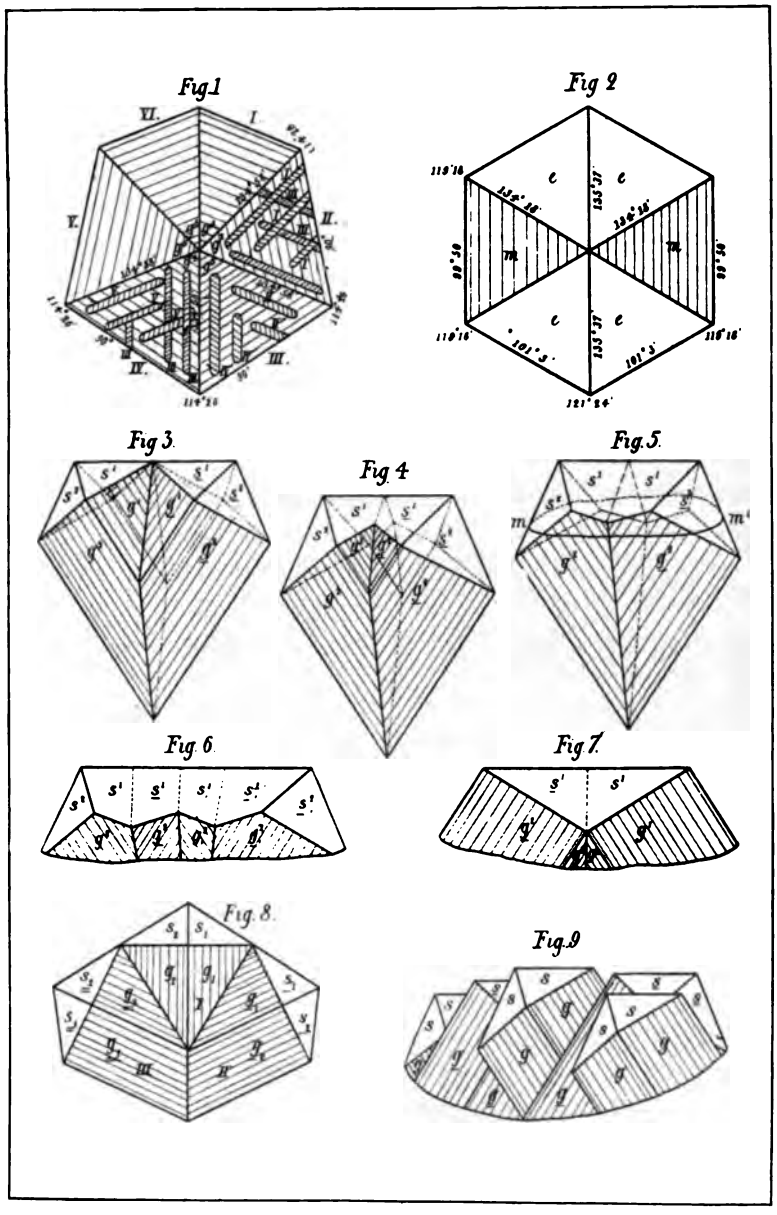
In a part of Bauer's paper on paramorphs of rutile after brookite* he discusses a new twinning law of rutile.

He states that although from the discussions of paramorphs it is evident that there are many examples of true paramorphs of rutile after brookite as described by von Rath, there were also some varieties described by him as being such, which were, however, never brookite crystals, but were always rutile.

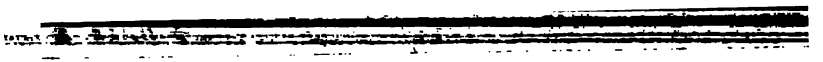
Certain twin forms of rutile imitate so closely the ordinary form of arkansite, which is made up of the striated faces $M=\infty P$ (110) and the smooth faces $e=P\breve{2}$ (122), that they might easily be mistaken for the latter.

The arkansite form shown in fig. 2, pl. 21, (in which it is so drawn that the macrodiagonal b stands at right angles to the plane of the paper) has a dihexahedral appearance similar to that which a rutile sixling (composition plane ∞P (110)) may have when the crystal is bounded only by the deeply striated prisms $g=\infty P$ (110). Such a composite crystal where the principal axes of the six individuals all lie in the plane of the paper is shown in fig. 1, pl. 21. The angles marked on the figures and the variation in the direction of the striation of the faces give the points of difference between the two minerals. Crystal measurements in some cases showed that rutile and not brookite was present. The rutile crystals sometimes occur with all six individuals present or with only some of them, as for example, II, III and IV (Fig. 1, pl. 21,) so that the crystal has three broad faces where the three other individuals should be. As is common in such rutile combinations some of the rutile individuals extend over the other neighboring ones; thus on the face of the apparent dihexahedron (Fig. 1, pl. 21,) narrow, elongated crystals which are parallel to the polar edges of the dihexahedron are formed. Each face g has or may have two such systems of parasites which often intersects each other as on individuals II and IV, or do not touch each other as on III. Each of these small crystals is bounded on the top by a flat face which is parallel to the face g of the main crystal complex, whose intersection with the face g on which the small crystal is situated is parallel

* See pages 317ff. of this report.



BROOKITE AND RUTILE FROM MAGNET COVE (AFTER BAUER).



to the longer axis of that crystal. Thus the small crystal marked III on g_1 is bounded above by a face parallel to g_3 etc. These faces of the small crystals are striated in precisely the same way as the faces of the crystal complex to which they are respectively parallel and it is therefore evident that they are only continuations of an intermediate individual over the faces of the adjoining individuals. The small crystals are not always as regular as those shown in the the figure for they are not always parallel to the edges and often by crowding together they form rough areas on the apparently dihexahedral faces. The multiple twins are not uncommonly made up of crystals which themselves consist of parallel, prismatic or acicular crystals which are above and below terminated by pyramidal faces. G. vom Rath pictures this * and it is only necessary to substitute the letter g referring to the rutile face in place of his M and e which refer to brookite to make his drawing applicable to this case.

The rutile of Magnet Cove often assumes by another peculiar form of twinning a rhombic habit, which might be mistaken for arkansite. This is the more easily possible since these crystals are black like the arkansite and not red like the common rutile.

While in the rutile twins already described the twinning plane $P\breve{\infty}$ (101) is also the composition plane in this case the composition plane is perpendicular to the twinning plane. This is shown diagrammatically in figures 3–5, plate 21. Two faces of the principal pyramid, $s = P$ (111), viz: s' and s', which are inclined forward give reflections at the same moment and therefore lie in the same plane and the pair of rear faces s are also situated in a similar manner. The latter cut the former in a single, straight line which is represented as horizontal in the figure, and form an angle $s : s$ 123° 8′ which is that of rutile. The cleavage and specific gravity also correspond with those of rutile. Since the edges made by the two pairs of pyramidal faces lie in the same straight line the pyramids of the second order which symmetrically truncate these edges fall into one plane and form the

* Verhandl. des naturhistor. Vereins für Rheinland und Westphalen, Band XXXIV., on plate 1., fig. 12 and Pogg. Annalen, Band CLVIII., p. 187, on plate V., fig. 13. See also fig. 31, on page 309 of this report.

twinning plane.* The directions of the striated prism faces g' and g' indicates that the composition plane is at right angles to the twinning plane. In fig. 3, pl. 21, the faces s of both the individuals are completely formed while in figs. 4 and 5, pl. 21, the two individuals are somewhat pressed together so that the middle faces s do not retain their full size; in fig. 5, pl. 21, moreover, the middle faces g' and g' which formed re-entrant angles in figs. 3 and 4, pl. 21, do not appear. Fig. 5, pl. 21, presents a great similarity to the heart-shaped twins from the Ural Mountains, Brazil, etc., but if the composition and twinning plane were $3P\infty$ (301) as in that case the faces s' and s' would make a re-entrant angle of 170° 28′ with each other and the straight edge along the top of the twin would be broken by a re-entrant angle of 169° 9′. It is not fully established, according to Bauer, that the law, twinning and composition face $3P\infty$ (301) is correct for the heart-shaped crystals and the fact that Hessenberg describes a crystal from Magnet Cove in which he detected both the twinning laws $3P\infty$ (301) and $P\infty$ (101) leads him to believe that the former was confused with the law just enunciated by him.

These crystals are generally so arranged that they are attached near the point where the prism faces g form their upper angle and hence the crystals are bounded almost solely by the pyramid faces s. This is indicated in fig. 5 pl. 21, by the irregular line m m; that portion above this line forms the crystal while that which is represented below the line does not exist in most of the natural crystals. Figures 6, 7 and 9, pl. 21, illustrates the same thing. The upper end of fig. 5, pl. 21, apparently represents an orthorhombic crystal which would be more likely to be referred to arkansite than rutile and it is only after a careful examination that its true character appears.

* It appears to the writer that the composition plane might be considered the twinning plane as well as the plane $P\infty$ (101) for a revolution of 180° about an axis perpendicular to it would cause the two portions of the twin to form parts of the same crystal. The plane has the crystallographic position of a steep pyramid of the second order and makes an angle of 32° 4′ with the vertical axis. The pyramid $\frac{12}{5}P\infty$ (12.0.5) makes an angle of 32° 53½′ with the vertical axis which approaches that made by this composition plane, but is not exactly identical with it. Since this plane is determined directly from the pyramid $P\infty$ it would be expected that it would have a simpler form.

These crystals, moreover, form polysynthetic twins, as is shown diagammatically in fig. 6, pl. 21, and in such cases also the apparently orthorhombic form is always present.

The single individuals, however, do not often in nature form regular straight rows, but are more often arranged as in fig. 9, pl. 21, alternately before and behind each other. Apparently complicated twinned masses are thus formed and in them the pyramid faces *s* give simultaneous reflections, while the striated prism faces, although quite small, intersect each other as shown in the figure.

Forms like those shown in fig. 7, pl. 21, appear to occur, but have not been determined with sufficient accuracy. The four individuals twin according to the law just described, but in this case they have changed places so that the individual which in figs. 3 and 5, pl. 21, was on the right-hand side is here on the left. In this case the prisms below, instead of converging, diverge from each other. The faces s' and $\underline{s}'$ reflect simultaneously.

Further complications arise when twins parallel to $P\infty$ (101) are combined with those just described and when cyclic twins, such as are common for rutile, combine with those formed by this law such complicated figures result that it is extremely difficult to place all the individuals in their proper relative positions.

According to this same law trillings are occasionally formed, as is shown in fig. 8, pl. 21, and the conditions are then such that a central individual has a crystal attached to it on both sides in such a way that the faces s_1, and $\underline{s}_1$, of the two individuals I and II reflect at one time and in the same way faces s_2 and $\underline{s}_2$ of I and III reflect at the same instant and the prism faces lie as shown in the figure. It appears, also, as if occasionally the other polar edges of the individual I were occupied by twin crystals so that a fiveling, like that which occasionally occurs on cassiterite, is formed.

In nature these trillings are fully as complicated in their structure as the twins pictured in figure 6, pl. 21, so that the

prism faces are seldom present and the individuals incline forward and backward as in fig. 9, pl. 21.

The rutile crystals which are found implanted on the surface of the hematite crystals described below are always single individuals and are seldom more than 2mm in length. They are of a dark, blood-red color, very brilliant, are bounded by the planes ∞P (110), and $\infty P\infty$ (100), and P (111), and lie on the base (001) of the hematite crystal in such a way that their principal axes are parallel to the edges made between the base (0001) and the negative rhombohedrons ($1\bar{1}01$).

Hematite occurs sparingly on the hillside at the western side of the Cove not far from Perofskite Hill. The crystals are usually found in the stream between this hill and the western hill and occur as far up the hill towards the west as the Paleozoic rock extends.

Two varieties have been found viz.: the large flat plates, 20 to 25mm in diameter, which are bounded by the base (0001), and a positive rhombohedron ($10\bar{1}1$). Other faces have been detected on some of the crystals, but they are too imperfect to be accurately determined. It is on such crystals as these that the rutile crystals occur.

The second variety of crystals consist of what are knows as "iron roses" (eisenrosen). These are seldom more than 5 to 8mm in diameter and are made up of numerous, very thin plates arranged in rosettes so as to resemble a full blown rose. These crystals are very similar to those found on St. Gothard Mountain in Switzerland.

Both of these varieties of hematite are imbedded on the sandstone or are loose on the surface and in direct association with it. They are probably related to menaccanite (ilmenite) in their chemical composition.

B. Contact Minerals from the Calcite.

The minerals which make up this group are found at the various points in Cove Creek where the calcite already described (pages 183 and 184) occurs and also on Perofskite Hill just southwest of where the Hot Springs and Malvern highway crosses

Cove Creek. Although no calcite can now be found in place on this slight rise it is more than probable that it was once present in quite large quantities and that on decaying it left behind the numerous lime silicates, titanates, etc., so characteristic of such formations elsewhere.

Perofskite (*Dysanalyte*) is perhaps the best known of all the Magnet Cove minerals which fall under the head of lime contact minerals and hence it will be considered first. According to James D. Dana* perofskite was first mentioned from Magnet Cove by C. U. Shepard, who described it as occurring "in black cubo-octahedrons."

The specimens of this mineral which commonly occur differ very much in the development of the faces which bound them. By far the most common form is that of an octahedron (111), whose corners are truncated by larger or smaller cube faces

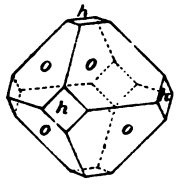


Fig. 35.

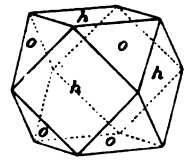


Fig. 36.

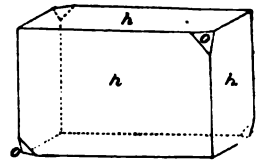


Fig. 37.

Perofskite from Magnet Cove.

(100) (Fig. 35.) In some cases these octahedral planes just touch at the corners leaving the cube faces as squares with their corners at the centers of their original edges (Fig. 36.) Then again cubes with only very slight octahedral truncations of the corners are not uncommon. These cubes are usually elongated in the direction of one of the principal axes making right rectangular parallelopipedons which are often twice as long as they are broad (Fig. 37.)

The crystals from this locality were used by Alfredo Ben Saude in the investigations upon the optic properties of this mineral which were described in his paper entitled "Ueber den Perowskit."† Ben Saude examined orientated sections of perof-

* A System of Mineralogy, 5th Edition, 1868, p. 146. (No reference is given and no notice of this mineral could be found by the writer among any of Shepard's notes on the minerals of this region).

† "Ueber den Perowskit von Alfredo Ben Saude." (Gekrönte Preisschrift) Göttingen. 1862.

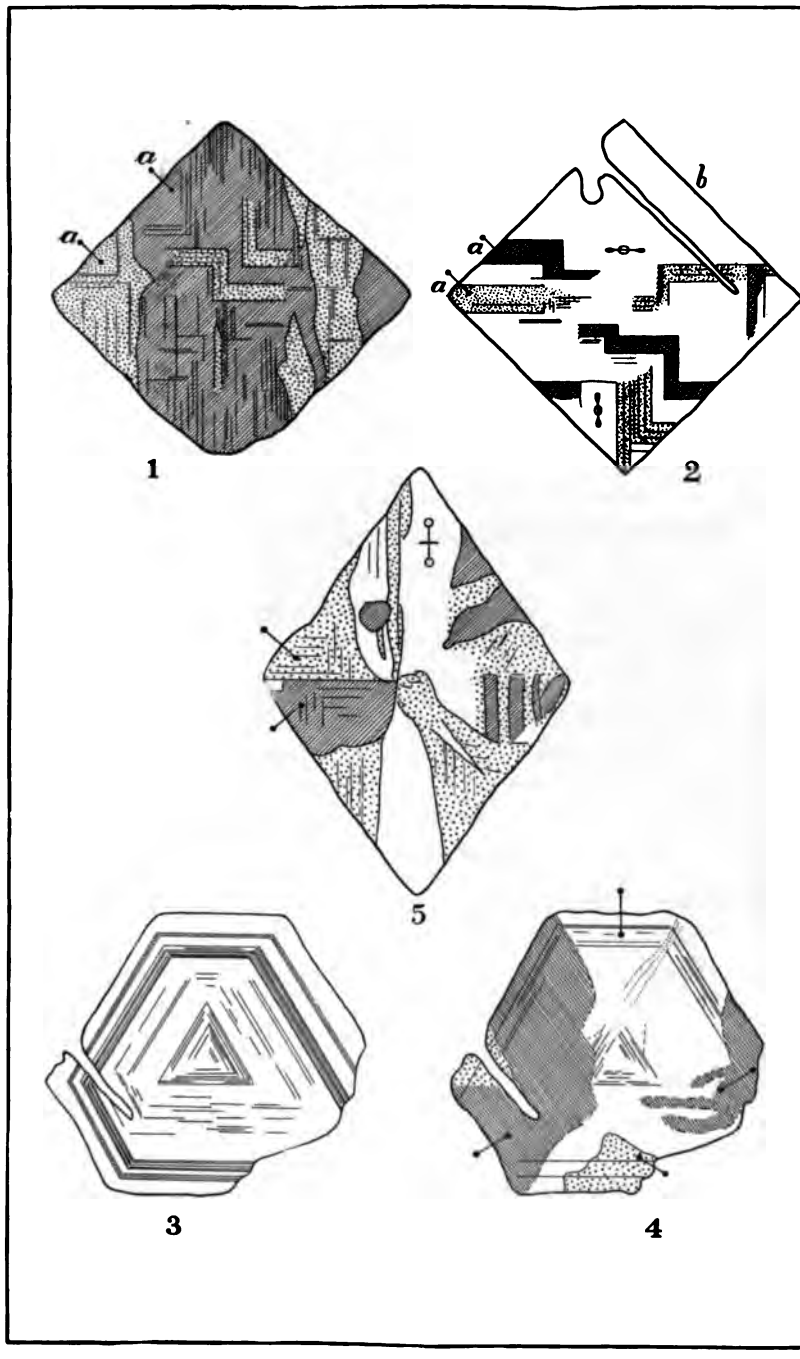
skite from various localities and among them those from Arkansas play an important part.

He examined a section of an octahedral crystal which was cut parallel to the cube face (100). This section was of a brown color and showed considerable pleochroism. Between crossed nicols it was seen to be made up as shown in figs. 1 and 2, pl. 22. Two more or less distinct systems of lamellæ lie parallel to the diagonals of the section and are extinguished parallel to its boundaries. Outside of these systems of lamellæ the section appears nearly or quite optically inactive.

In convergent polarized light two hyperbolas are generally seen lying in the optically active lamellæ and these form a cross when the sides of the section of the octahedron are parallel to the planes of the nicols. The inactive parts of the section show a single optic axis and it is found that the position of the black bar passing through this is dependent upon its position in the section. Thus in two different parts of the section the bars stand at right angles to each other (Fig. 2, pl. 22.) In fig. 1, pl. 22 no such inactive zone occurs and therefore no single axis appears, but only pairs of hyperbolas about a bisectrix are seen.

Sections from octahedral crystals cut parallel to an octahedron (111) present such an appearance as is shown by figs. 3 and 4, pl. 22. Fig 3, pl. 22, represents the section as seen in non-polarized light and shows a decided zonal structure. Fig. 4, pl. 22, represents the same section in polarized light. When a selenite plate is used the shaded portion of the section appears green, the dotted portion yellow and the white portion red. In convergent light the bars passing through the optic axes are eccentrically arranged and the positions of the planes of the optic axes are found to be at right angles to the sides of the section. Lamellæ are also occasionally observed.

Last of all Ben Saude describes a section cut from an octahedral crystal parallel to a face of the dodecahedron (110). Such a section is shown in fig. 5, pl. 22. The plate is indistinctly divided into quadrants in which areas of different orientation occur. It is comparatively free from systems of lamellæ. The interior portion of the section usually consists of an area



SECTIONS OF PEROFSKITE FROM MAGNET COVE. (AFTER BEN SAUDE.)

which extinguishes parallel to the diagonal of the rhomb, while the portions about the edge extinguish at angles of 45° on both sides of the shorter diagonal. By the use of a selenite plate the section is seen to be bluish green where the shaded portion is shown, yellow where the area is dotted, and red where the section is left white. In the portion which extinguishes parallel to the diagonals of the rhomb two axes about a vertical bisectrix are observed, but in the portions which extinguish at an angle of 45° only one axis appears.

Ben Saude did not succeed in getting good etched figures from the Arkansas crystals and although he devotes a large portion of his paper to the appearance of the etched figures on crystals from other localities he makes no mention of those from Arkansas.

No analyses appear to have been made of this material until very recently, when F. W. Mar published a paper entitled "On the so called Perofskite from Magnet Cove, Arkansas,"* in which he shows its relation to the mineral *dysanalyte* determined by Knop † as constituting the supposed perofskite of the Kaiserstühl in Germany. Mar gives his method of analysis and then his results in per cents and calculates the quantivalence ratio of the oxides.

It appears from the following analyses that the mineral from Magnet Cove holds an intermediate place between dysanalyte and theoretical perofskite. It is probable that none of the older analyses of perofskite given in Rammelsberg's Mineralchemie are correct and that a revision of them would show that larger or smaller amounts of niobium, tantalum and other metals of the cerium group are present in almost all of them. The question as to whether the Magnet Cove mineral should be grouped under the dysanalyte of Knop or with perofskite proper can, therefore, only be determined by a re-examination of the older perofskite analyses and by an exact determination of the rare earths that this mineral contains. In this report, therefore, the name *perofskite* will be retained for the Magnet Cove mineral.

* Am. Jour. Sci., Series 3, Vol. XL, 1890, p. 403.

† Zeitschr. für Kryst. Band I., 1877, p. 284.

For the purpose of comparison the analysis of Mar is placed beside other analyses and the theoretical composition.

Analyses of perofskite and dysanalyte.

CONSTITUENTS.	I. Dysanalyte. Kaiserstühl, Ger.	II. Magnet Cove, Ark.	III. Perofskite Zermatt, Switz.	IV. Theoretical $CaTiO_3$
TiO_2	41.47	42.12	59.12	58.83
SiO_2		0.08		
Nb_2O_5	23.23	4.38		
Ta_2O_5		5.08		
Ce_2O_3	5.72	0.10		
$(La, Di)_2O_3$				
$Yt, Er)_2O_3$		5.42		
Fe_2O_3		6.16		
FeO	5.81	0.23		
MnO	0.43		6.11	
CaO	19.77	33.22	35.81	41.17
MgO		0.74		
Na_2O	3.57			
Total	100.00	99.53	101.04	100.00
Sp. Gr.	4.13	4.18	4.038.	

I. Dysanalyte. Voigtsburg Kaiserstühl, Germany. Analy. by Knop. N. Jahrb. für Min., Jahrg., 1877, p. 647.

II. Perofskite or Dysanalyte, Magnet Cove, Ark. Analy. by F. W. Mar, Am. Jour. Sci., Ser. 3, Vol. XL, 1890, p. 403. (loc. cit.)

III. Perofskite. Findelengletscher near Zermatt. Switzerland. Analy. by Damour. Ann. Min. (4) 6, p. 512.

IV. Theoretical composition of Ca TiO_3.

Hydrotitanite is a name given by König* to the altered varieties of perofskite from Magnet Cove. The perofskite is often coated with a yellowish brown or gray incrustation which has been shown by König to be perofskite from which much of the lime has been extracted and water added by meterologic action. In some cases this is only superficial while in others it extends almost or entirely through the crystal.

* Proc. Academy Nat. Sci. of Phila. 1876, p. 82.

The analysis given by König is as follows:—

Analysis of hydrotitanite (König).

TiO_2	82.82
Fe_2O_3	7.76
CaO	0.80
MgO	2.72
H_2O	5.50
Total	99.60
Specific gravity	3.581

The perofskite and hydrotitanite both occur on Perofskite Hill as well as occasionally in the calcite found in the creek. It is evident, therefore, that they are to be considered as metamorphic minerals. It is also very commonly found attached to octahedrons of magnetite and with these is often imbedded a mass of fine apatite crystals.

Magnetite occurs not only in the calcite and, as just described, with apatite, but also in large quantities with the calcareous tufa which overlies the calcite. It consists of octahedral crystals which are often as much as 20mm in diameter. The only faces which have been observed are the octahedron (111), the rhombic dodecahedron (110) and the ikositetrahedron $3P3$ (311). In their intergrowths with perofskite no definite relations between the positions of the axes of the two minerals is observable.

Apatite occurs in large masses of radiate and parallel needles imbedded in the coarsely crystalline calcite. The crystals seldom exceed 1mm in diameter and are usually much smaller. They are frequently of a very light green color and it is not uncommon to find both light yellowish brown and pure white masses of such crystals in close proximity.

These apatite masses resemble very strongly those already described (page 220) but these are of metamorphic origin, while those were formed in the igneous rock itself.

Biotite or phlogopite occurs in the metamorphosed calcite and forms sharp, six-sided prisms and plates of a dark, pistachio-green color. Thin cleavage plates of this mica are transparent

and green and when examined under the microscope in convergent polarized light they are seen to be almost uniaxial. The optic axis angle in no case exceeds 3°. The plane of the optic axes is the symmetry plane of the crystal and the mica is therefore classed with those of the second order. From the color and small optic axis angle the mica would be considered to be a biotite, while its occurrence in the metamorphosed calcite would suggest that it is a phlogopite.

Vesuvianite occurs as crystals which occasionally reach a very large size. One specimen in the possession of the writer measures 80mm in length, but it is by no means a perfect crystal. Some of the smaller crystals are very sharp and well formed and even the medium sized ones often show faces some parts of which give sharp reflections. The crystals are usually doubly terminated and the pyramidal faces are often connected by remarkably small prisms, which in some cases are entirely wanting. (See fig. 38.)

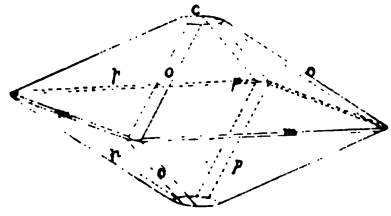


Figure 38. *Vesuvianite, Magnet Cove.*

The faces are as follows:— $p=P$ (111); $c=0P$ (001); $o=P\infty$ (101); $m=\infty P$ (110) (small); $\frac{1}{7}P$ (117); $\frac{7}{10}P$ (7.7.10). The following angles are the mean of several readings between the different pairs of faces indicated and that measurement which varies the most is added.

Faces.	Calculated.	Reading.	Greatest variation.	No. of readings.
$p : p$ (111) : (111)	50° 40′	50° 22′ 13″	50° 41′	7
$p : o$ (111) : (101)	25 20	25 10	25 34	5
$c : o$ (001) : (101)	28 15½	28 12	27 30	5
$c : \frac{1}{7}P$ (001) : (117)	6 12	6 25 (poor)	.....	
$c : \frac{7}{10}P$ (001) : (7.7.10)	28 01	28 40 (poor)	.....	

The two faces $\frac{1}{7}P$ and $\frac{7}{10}P$ are extremely narrow and give weak reflections which are, however, single and probably represent the faces indicated. The crystal on which these faces are found lack the basal plane, but show a short prismatic zone.

In crystal habit most specimens of this mineral from Magnet Cove approach very closely to the variety found in the Achmatow mine in the Slatoúst District of the Ural Mountains and figured by Kokscharow.* Others bear a strong resemblance to Vesuvianite from the Monzoni Mountains on the eastern side of the Fassa Valley in the Tyrol, which were figured by V. von Zepharovich.†

The color of these crystals varies from an oily, yellowish green to an olive-green and in rare cases passes into a yellowish or reddish brown.

The hardness, cleavage and other physical characteristics are normal and require no special description or enumeration here.

Under the microscope in convergent polarized light a thick section cut at right angles to the vertical axis shows, in some parts of the section, a perfect uniaxial interference figure while in other parts of the same section a separation of the black cross into two hyperbolas whose angular distance does not exceed one degree is observed. The crystal when tested with a mica plate shows the negative character of its double refraction.

In thin sections parallel to the principal axis the mineral is nearly colorless and weak in its double refraction. In one section a large number of minute colorless prisms are found scattered throughout the crystal in great profusion. In some cases these are one millimeter in length and of about one tenth that in breadth. They consist of hexagonal prisms truncated on the ends by comparatively steep pyramids. They are transparent and colorless and when examined between crossed nicols have a parallel extinction. When tested with a selenite plate they show the character of their double refraction to be negative. In a few cases irregular cracks at approximately right angles to the vertical axis are observed. These tests all indicate that this included mineral is apatite. In some of the vesuvianite none of of these inclusions of apatite appear but in other specimens they

* Mat. Min. Russlands, Band I., 1853, p. 97. Cited after Handbuch der Mineralogie von C. Hintze, Band II., 1890, p. 299.

† Wiener Akad. Band 49, p. 94. Cited as above.

are present in large quantities. It is uncommon to find inclusions of any kind in vesuvianite for Rosenbusch * states that although this mineral occasionally surrounds associated substances as calcite and pyroxene and contains fluid inclusions still there are no inclusions which are characteristic for the mineral and it is usually perfectly pure and homegenous.

A chemical analysis of one of the best and purest of these vesuvianite crystals gave the writer the following results:—

Analysis of vesuvianite.

SiO_2	36.68
TiO_2	0.72
X(*)	0.80
Al_2O_3	16.14
Fe_2O_3	5.56
FeO	1.08
CaO	35.52
SrO	Trace.
MgO	0.96
K_2O	0.19
Na_2O	0.26
H_2O (loss)	1.83
Fl	0.00
Total	99.74

(*) For the meaning of X see p. 226.

A test for fluorine gave negative results.

The analysis, with the exception of a rather large percentage of iron, shows the mineral examined to be an exceptionally pure variety. A thin section of the mineral analyzed showed that the apatite described in some of the other specimens was wanting in this one.

Monticellite occurs in large crystals and grains which range from 1 to 20mm in diameter. It is imbedded in the coarse crystalline calcite in the form of crystals and nodular masses precisely as the vesuvianite is and it occurs associated with the same minerals.

The crystals were first brought to the notice of the writer by Wm. J. Kimzey of Magnet Cove.

* Mikrosk, Physiog, Band I., p. 321.

R. N. Brackett, chemist of the Survey, made a rough quantitative analysis of the nodular material and the writer made a number of measurements on some of the larger crystals with a contact goniometer. The results of both of these investigations showed conclusively that the mineral in question was monticellite.

At about that time word was received from Dr. E. S. Dana that a paper had been submitted to him for publication in which monticellite from Magnet Çove was described and figured. As this paper had the right of priority the writer went no further with his investigation of this mineral, but was enabled through the kindness of Dr. Genth and Mr. Pirsson, the authors of the paper on monticellite, to see the advance sheets of their article * and to make the following notes.

Pirsson, who undertook the crystallographic part of the work, observed the following forms on the two crystals which he measured: $b=\infty P\breve{\infty}$ (010); $s=\infty P\breve{2}$ (120); $m=\infty P$ (110); $k=2P\breve{\infty}$ (021); $d=P\bar{\infty}$ (101); $e=P$ (111).

He states that the brachydome (021) and the brachypinacoid (010) are quite largely developed and that in these respects the mineral from Magnet Cove differs from those of the European localities. The dimensions of the crystal figured (Fig. 39) are given by Pirsson as follows: height 3 ctm; breadth nearly 2 ctm and thickness parallel to the brachy-axis a little more than 1 ctm.

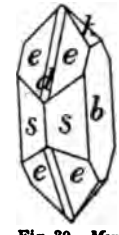


Fig. 39. *Monticellite from Magnet Cove (after Pirsson).*

In the figure given the unit prism (110) is not shown, but it was observe by Pirsson on the second crystal measured.

The axis ratios used by Pirsson are those of vom Rath,† but in order to bring this mineral into accord with the olivine group, the vertical and brachy-axes must be halved.

The ratios then become:—

$$a : b : c = 0.433689 : 1 : 0.57569$$

* Am. Jour. Sci. Series 3, Vol. XL, 1891, p. 398.

† Pogg. Ann. Erg. Band V., 1871, p. 434.

and the measured and calculated angles become:—

	Faces.	Measured angles.	Calculated angles.
$b : k$	010 : 021	41° 11′	40° 58½′
$b : e$	010 ; 111	70 50	70 53½
$s : s$	130 : 120	82 07	81 52
$s : e$	120 : 111	38 19 (38° 22′)	38 19
$b : s$	010 : 120	48 30	48 04
$e : d$	111 : 101	19 08 (19° 08′)	19 06½
$m : m$	110 : 1$\bar{1}$0	47 01	46 53½

The physical properties given by Pirsson are as follows:—

"Fracture conchoidal to splintery, brittle; H. = 5 Sp. gr.=3.108. From colorless to brownish white and light brown. Luster vitreous on the fracture, inclining to greasy on the crystal planes."

Genth in making the analysis powdered together the mineral and the calcite in which it was imbedded and by means of a Thoulet's solution separated the two minerals. He then separated the magnetite by means of a magnet. He found considerable quantities of phosphoric acid and by a careful microscopic examination he detected minute needles of apatite.

The two analyses which he made gave the following results:—

Analyses of monticellite (Genth).

CONSTITUENTS.	a.	b.
SiO_2	38.47	38.46
Al_2O_3	0.16	0.19
FeO	5.09	4.93
CaO	35.18	35.31
MnO	1.11	1.13
MgO	20.71	20.52
P_2O_5	1.98	2.08
Ignition	2.28	2.29
Total	99.98	99.91

Genth then deducted the P_2O_5 and a sufficient quantity

of CaO to form $Ca_5F(PO_4)_3$ (fluorapatite) from the analysis and recalculated the analyses to 100 per cent.

The resulting figures are as follows:—

Analyses of monticellite recalculated (Genth).

CONSTITUENTS.	a.	b.
SiO_2	35.08	35.19
Al_2O_3	0.17	0.20
FeO	5.33	5.18
CaO	34.16	34.25
MnO	1.16	1.19
MgO	21.71	21.58
Ignition	2.39	2.41
	100.00	100.00

If the water is omitted this approaches very closely to the formula $(Mg, Mn, Fe)_2 Sio_4 . Ca_2 SiO_4$.

The presence of over two per cent of water is peculiar as the powdered mineral had been dried over sulphuric acid for several days before it was analyzed.

The writer (J. F. W.) has noticed that in many cases the unit prism is very strongly developed as mentioned by Pirsson and in some cases it has become so prominent as to quite alter the appearance of the crystal. (Fig. 40). The crystal from which the figure is taken is about 5cm in length and 2cm in breadth and thickness, being nearly equal in these two dimensions. The faces observed are those mentioned by Pirsson as having been noted on these crystals, with the exception of the macrodome (101) which is absent on the crystal figured by the writer. The same notation of faces as that used by Pirsson has been adopted.

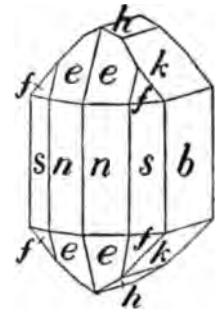


Fig. 40. *Monticellite from Magnet Cove.*

III. RELATION OF THE IGNEOUS ROCKS OF MAGNET COVE TO EACH OTHER AND TO THE ADJACENT SEDIMENTARY ROCKS.

The igneous rocks of Magnet Cove are divided into three genetically distinct groups whose structure and mode of occurrence show that they were formed during three distinct periods of igneous activity.

The oldest of these consists of the basic, eleolitic, abyssal rocks which constitute a large part of the interior Cove basin. The large masses of these rocks are holocrystalline granitic in their structure and were cooled slowly and under pressure. About the edges of this mass a porphyritic variety of these rocks often occurs and in some cases cracks in the surrounding rocks are filled with materials from this basic magma thus forming basic, eleolitic, porphyritic and lamprophyric dikes.

The next period of igneous activity is one which corresponds to the dike forming epoch of the Saline County region. During this period the rock in and about the Cove which had been disturbed and heated by the intrusion of the masses of abyssal rocks cooled and cracks opened in all directions. These cracks are filled with monchiquitic rocks of all varieties which appear as the basic, dark, non-eleolitic dikes, so numerous in the neighborhood of the Cove and in fact everywhere throughout that part of the state. (See chap. XIII).

The third and last period of igneous activity is that in which the eleolitic and leucitic rocks of the "Cove ring" were formed and during which the numerous tinguáitic dikes of all varieties were intruded. The rocks of this period are all of an intrusive character, a fact which is shown both by their structure and mode of occurrence.

These youngest rocks cut both the abyssal rocks (p. 188) and the dikes of monchiquite (p. 174), and are therefore proved to be younger than either of those groups.

All the igneous rocks are younger than the surrounding Paleozoic rocks* and have forced their way into them.

* See note by John C. Branner in Proc. A. A. A. S., Vol. XXXVII., 1888, p. 188.

They were formed after the folding and bending and after some of the erosion of the Paleozoic rock had been accomplished, probably during late Cretaceous times.

The rock now found in and about the Cove shows no evidence of having been effusive in the sense in which that term is used in petrography. The occurrence of the abyssal rock in the Cove center and the numerous dikes about the border, separated from each other only by narrow beds of sedimentary rock indicate an intrusive and not an effusive rock. If a true eruption took place over the whole Cove or at any part of it, it would be natural to expect some indication of such action in the form of glass, scoria, tufa or ashes, but nowhere about the Cove nor even anywhere in Arkansas where the detritus from the Cove is deposited has any such material been found.*

On the other hand since the intrusion of the igneous rocks the erosion which has taken place, although probably entirely subaërial, has been very great and all such truly volcanic material had it ever existed might have been carried away and become entirely disintegrated in the transit.

It is certain that the rock which now appears at Magnet Cove is in the form of abyssal masses and of large and small dikes, but whether these dikes are simply the pipes through which the igneous matter erupted to the surface or are intrusive dikes which did not afford effusive material, is a question which cannot be definitely answered from the data at hand.

The writer is, however, of the opinion that these igneous rocks are *intrusive* in the restricted sense of the word and the rocks described in this report have been classified and named in accordance with this conviction.

* The ash-beds described in chapter X. II. are of a much earlier origin and are interbedded with rocks which were formed long before the intrusion of the igneous rocks exposed in the state.

CHAPTER IX.

Geographic and Petrographic Description of the Potash Sulphur Springs Region.

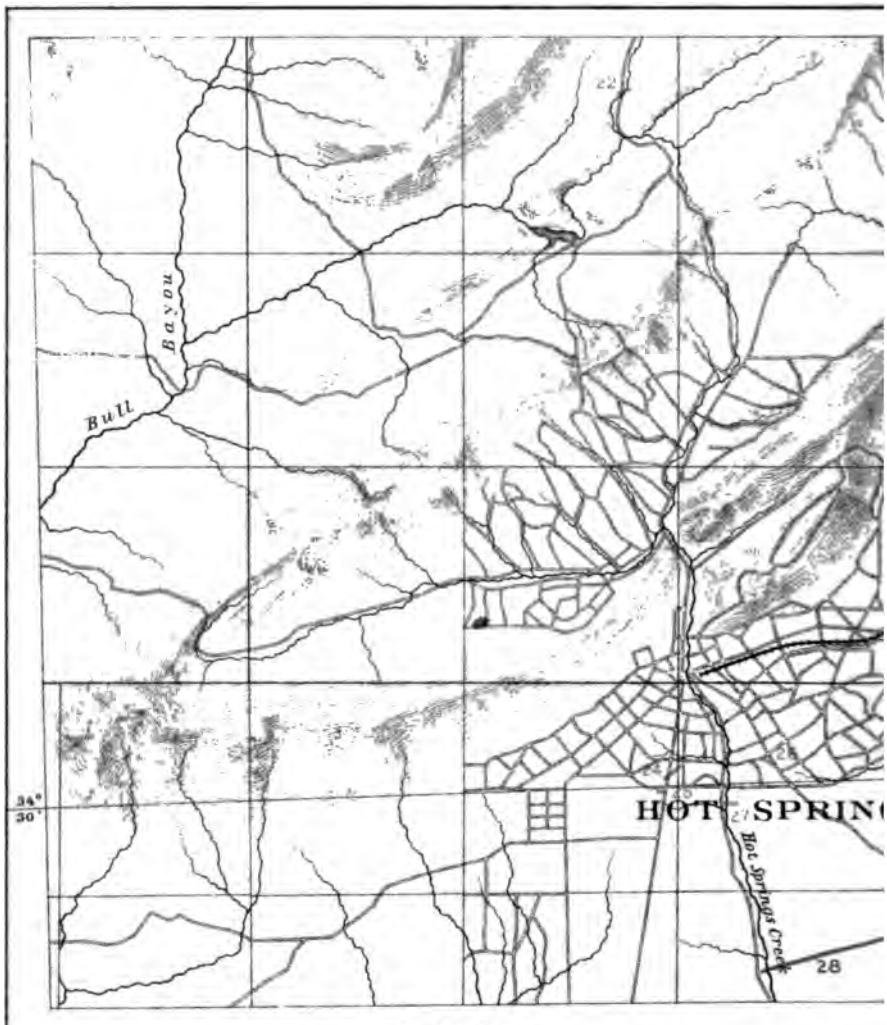
I. Distribution of Igneous Rocks.
II. Petrographic Description of the Igneous Rocks.
A. Eleolitic Rocks.
1. Eleolite sodalite syenite.
2. Eleolite garnet porphyry.
3. Eleolite Tinguáite.
a. Border type.
b. Dike type.
B. Augitic Rocks.
III. Contact Rocks and Minerals.
IV. Potash Sulphur Water.
V. Relations of the Igneous Rock to each other and to the Sedimentary Rocks.

I. DISTRIBUTION OF IGNEOUS ROCKS.

The igneous rocks about Potash Sulphur Springs cover in all about three-quarters of a square mile (20 ares) but even in this comparatively small area they show many types and varieties. The rock is situated in township 3 S., range 18 W. and occupies the western portion of section 17 and the eastern half of section 18.

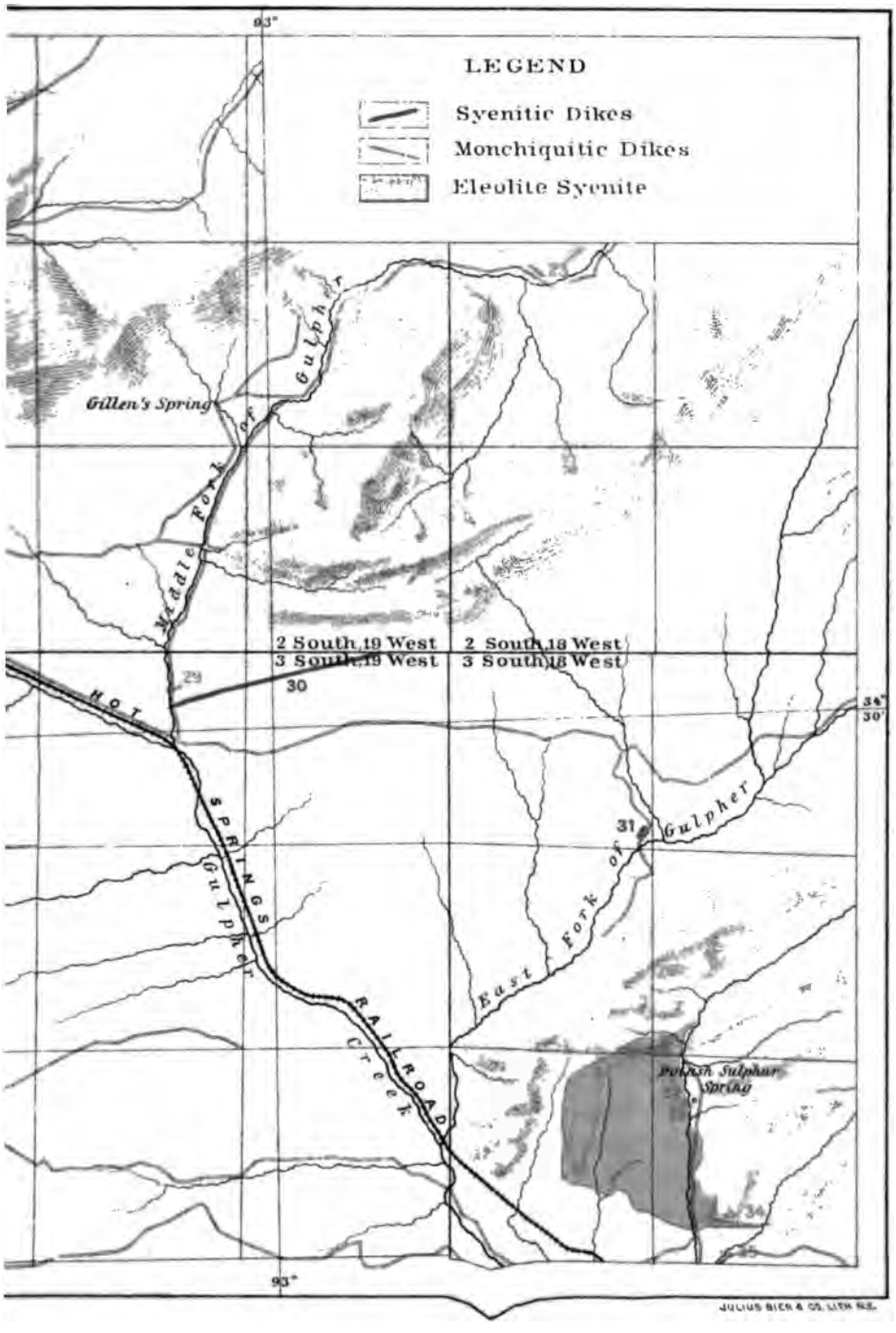
Perhaps the most satisfactory way in which to describe this region is to take the Potash Sulphur Springs hotel (3 S., 18 W., Section 17, center of N. W. quarter) as a starting point and consider all the other localities with reference to it.

As will be seen from an examination of map V. the hotel is situated in a small, level space at the foot of a novaculite



A MAP
showing
THE IGNEOUS ROCKS
NEAR
HOT SPRINGS
To accompany Vol. II of the annual report of
THE GEOLOGICAL SURVEY OF ARKANSAS
for 1890.

SCALE 0 1 2 3 Miles
0 1 2 3 4 Kilometers


LEGEND
Syenitic Dikes
Monchiquitic Dikes
Eleolite Syenite
93°
Gillen's Spring
Middle Fork of Gulpher
2 South 19 West
3 South 19 West
2 South 18 West
3 South 18 West
30
29
31
34°
30'
HOT SPRINGS
Gulpher Creek
RAILROAD
East Fork of Gulpher
Potash Sulphur Spring
34
93°
JULIUS BIEN & CO. LITH. N.Y.

ridge and stands close to the bank of the Potash Sulphur Branch of Sulphur Creek. The novaculite ridges in this region all trend in a generally southwest direction and form the most striking features of the landscape. On the west the hills come somewhat nearer the stream than on the east, but are not nearly so high. The western hill forms an irregular, broad-topped elevation and is bounded on its western side by a valley beyond which rises a much steeper hill resembling quite strongly a novaculite ridge. Both north and south of the hotel the stream finds its way between high ridges and forms a very important agent in exposing the rocks along its course. North of the syenite area lies Bald Mountain, another novaculite ridge, and by far the highest and most important one in this immediate vicinity. At its highest point it is about a thousand feet (300m) above the level of the Gulf of Mexico and it forms a striking feature in the landscape.

The greater part of the igneous rock lies west of Potash Sulphur Branch and forms the hill or group of hills on that side of the stream for nearly half a mile (0.8km). The north line of contact between the sedimentary rocks and the syenite begins at the creek and extends west across a southern spur of Bald Mountain. The general character of the rock is that of a coarse-grained eleolite syenite which in some cases shows large crystals of mica. The contact line between the novaculite and the igneous rock is comparatively straight, but there are places where dikes of the igneous rock extend out into the novaculite for several hundred feet. In one case such a dike appears in the form of large syenite boulders 6 feet (1.8m) in diameter. These dikes are usually rather fine-grained and have a greenish color. They contain much ægirite and are somewhat porphyritic.

The west line of contact runs nearly southwest from the western extremity of the northern boundary (3 S., 13 W., sec. 18 near the center of N. line of N. E. quarter) following the general trend of the novaculite ridge and keeping 20 to 30 feet (6 to 9m) above the bottom of the valley. This syenite occurs in loose

pieces mixed with the fragments of novaculite lying on the surface and, wherever a gully cuts through the surface, the decomposed syenite is found forming the underlying rock of that part of the hill. In most cases the character of the arboration is here, as at Magnet Cove, a sure indication of the character of the underlying formations. Thus wherever only hard wood is found and no pine whatever appears (unless it has recently been cut off) it is nearly certain that an underlying bed of syenite exists even if it is covered over with fragments of novaculite. On the other hand the occasional occurrence of a pine does not necessarily indicate that sedimentary rocks underlie it, but it has usually been found that where a few pines are scattered among the hard-wood trees the hillside consists of a number of dikes of igneous rock cutting the sedimentary beds.

The best exposed and best defined mass of eleolite syenite on the western side of the region is a mass of coarse-grained eleolite syenite which lies along the crest of the western ridge already mentioned. This is cut off on the south by the novaculites, but isolated masses of syenite and of the border or dike variety of tinguáite, occur above this along the north and east side of the novaculite ridge and then appear again in the valley to the east.

In the valley the rock is for the greater part covered up by loose detrital material and soil, but occasionally in the bottoms of the deep ditches cut by the streams the rock appears in the form of fresher dike-like masses included in the coarse-grained and very much decomposed eleolite syenite. These masses, as they approach the southern border of the area, become more eleolitic and darker in color and show a great similarity to the *cove type* of the Magnet Cove rocks (p. 208.) These rocks on decaying form a very productive soil and a flourishing vineyard on the top of the hill attests its good quality. In the soil of this vineyard many flakes of mica and loose pieces of garnet occur.

The coarse, eleolitic rocks extend to the Potash Sulphur Branch and either cross it, or form porphyritic bands on the western bank of the stream where they come in contact with the sedimentary rocks. This is the case at the Springs themselves, for

there the eleolitic rock covers the top of the hill, but just before it reaches the sedimentary rocks it becomes porphyitic and forms a brown syenite porphyry, or better a feldspathic tinguáite. This belt is about four feet (1.2m) thick and appears in the steep bank in an almost horizontal position. Below it occur the strongly metamorphosed sedimentary rocks from which issue the "potash sulphur mineral waters." This contact rock is extremely variable in its composition and in some places approaches so close to an igneous rock in its appearance and co mposition that it is almost impossible to detect the difference. The igneous rocks which appear again below this consist principally of bands of light and dark rock completely intermingled and cut here and there by masses and veins of calcite which often show a decidedly banded structure. The darker variety of rock evidently approaches very closely to the dark variety of eleolite syenite from Magnet Cove. The lighter bands consist of three varieties, namely, true eleolite syenite dike rock, such as is found cutting the darker variety at Magnet Cove; a light colored, granular contact rock containing much white wollastonite and a coarse- or fine-grained calcite which here and there contains other minerals, (See later). These rocks are cut at two points by fourchite dikes, one of which is only six inches (15cm) wide and runs out to a point under the surface of the stream directly west of the bowling-alley. The other dike is about 18 inches (45cm) wide and lies parallel to the first and about three feet (0.91m) south of it. They both have a northwest and southeast direction.

About two hundred feet (60m) below this point the igneous rock comes down to the stream and crosses to the eastern side. Here it forms a mass of syenite boulders which are, however, not far from in place. Extending south from these for some distance the igneous rock is found in the banks and cuts, in a very decomposed condition. About a quarter of a mile (0.4km) south of the hotel the syenite is found to extend further to the east and, in the form of dikes of igneous rock associated with bands of both metamorphosed and unaltered sedimentary rocks, makes up the western side of the hill, lying east of the road. On

the eastern side of the same hill the shales evidently predominate, but at one point near the southeast corner of the hill a dike of brown tinguáite similar to that found near the springs, cuts the shales in an almost due east and west direction. The dike is here about 3 feet (0.91m) wide. It appears in a small branch which flows into Potash Sulphur Branch from the east and in the bed of which, with the exception of the dike mentioned, nothing but shales could be detected. On passing over the south end of the hill due west from this point syenite and metamorphosed rock is found in abundance and on reaching the road two dikes of eleolite syenite, granitic in structure and about 50 feet (15.2m) apart, occur. These form the southern limit of the igneous rocks and although they appear only as boulders on the surface they may form considerable masses deeper down. They are bounded on both sides by bands of green tinguáite. On tracing these west onto the hill they gradually become covered with syenitic soil and loose fragments of syenite and shale intermingled, showing that the same mixtures of shale and igneous rock which have been mentioned occur here. This kind of syenitic soil extends nearly to the top of the low hill about which the road turns in passing from Potash Sulphur Springs to the railway station at Lawrence. From this hill the mixture of syenite dikes and metamorphosed rock extends to the north along the creek and widens out towards the west until it touches the rock already described as lying north and east of the western novaculite ridge.

Returning now to the road where the dikes of eleolite syenite cross it, it is found that for some distance toward the north the rock is principally metamorphosed shale and then, 300 feet (91m) north of the dikes just mentioned, appear the decomposed remnants of a 30 foot (9.1m) dike of eleolite syenite on both sides of which are very beautifully banded metamorphosed shales. In these occur the beautiful pink and white wollastonite crystals which were exposed when the rock was blasted open in building the road. North of this band of metamorphosed rock the syenite appears in a decomposed condition and seems to form the mass of the hill to the east.

II. PETROGRAPHIC DESCRIPTION OF ROCKS FROM POTASH SULPHUR SPRINGS.

The only petrographic notice of the rocks of this region was made by Owen* where he mentions a "quartz porphyry amongst which a calk spar rock is found" near Fairchild's mineral spring.

Many of the types already described from Magnet Cove occur among the syenitic rocks at or near Potash Sulphur Springs. Where these are identical or nearly so with the types already described no additional description of them is given, but in the few cases mentioned below the rocks appear to be somewhat different from any of the types already noticed and are consequently described separately.

A. Eleolitic Rocks.

1. Eleolite Sodalite Syenite.

The eleolite sodalite syenite is a medium-grained mixture of glassy sanidine-like feldspar crystals, pink eleolite and black prisms of pyroxene. It is quite holocrystalline and granitic in its general appearance and would form a beautiful building stone for interior work.

The microscopic physiography of only a few of the minerals which compose this rock need to be taken up in detail, for most of its components are identical with those described elsewhere.

Feldspar appears as a glassy, sanidine-like variety. It has a low double refraction and might easily be mistaken for eleolite were it not for its characteristic cleavage-cracks. It is clear and transparent and forms comparatively large allotriomorphic crystals which include idiomorphic crystals of eleolite and of sodalite.

Sodalite appears in small (0.5 to 1.0mm) idiomorphic crystals which are generally hexagonal in section. These have mostly been so altered by weathering that they show

* Second Report of a Geological Reconnoissance of Arkansas, p. 106.

slight polarization phenomena when observed with a selenite plate. These hexagonal sections might all be referred to eleolite, which also appears as phenocrysts in the feldspar were it not for the fact that a qualitative examination of the rock showed considerable quantities of chlorine indicating the presence of sodalite.

Eleolite is in the form of stout prisms which are always older than the orthoclase. They generally contain many alteration products in the form of cancrinite, hydronephelite and calcite.

Pyroxene appears under the microscope as light yellowish green sections of *diopside*. This mineral often appears in the form of numberless parallel needles which have been formed by the decomposition and regeneration of the original pyroxene substance.

Biotite is also observed and occurs in thin brown plates.

The rock as a whole presents a similar appearance to the mica eleolite syenite (Cove type) from Magnet Cove, but is finer grained and poorer in pyroxene.

2. *Eleolite Garnet Porphyry.*

The dark gray band of rock occurring near the hotel contains numerous black crystals and forms a rough, harsh stone.

Under the microscope it is seen to be porphyritic in structure and the dark crystals are found to be perfect brown garnets (melanite) often as much as a millimeter in diameter. These are imbedded in a groundmass consisting principally of plagioclase and diopside crystals. Both eleolite and diopside appear as phenocrysts.

Eleolite consists of stout hexagonal prisms which are often altered in great part to calcite and cancrinite.

Melanite forms perfectly sharp, idiomorphic crystals which have a brown or yellow color and show concentric zones of these two colors; the interior being usually the lighter and the outside rims the darker. They are in all respects perfectly normal.

Diopside occurs in small, lath-like crystals which are found only in the groundmass. They seldom exceed 0.07mm in

length and are very slender. They almost always form albite twins, in which the extinction on the two sides of the twinning-plane is comparatively small—not often over 12°, so that the crystals may be considered as belonging to the labradorite series. Around these crystals, and in some parts of the section forming a very important factor, is a transparent substance, which between crossed nicols appears white. On revolving the stage a spheroidal structure is observed in this material. When a section containing this material is etched with hydrochloric acid large cubes of salt are quickly formed showing that the substance contains much sodium. It is probable that it is the result of weathering on some mineral rich in sodium. The order of formation of the minerals making up this rock is as follows: Diopside, melanite, eleolite, orthoclase, labradorite, secondary minerals.

3. Eleolite Tinguáite.

a. Border type.

This rock appears macroscopically to be a typical tinguáite and is usually of a green or greenish brown to reddish brown color. It forms the borders of the larger masses of eleolite syenite (p. 347) and also of the smaller dikes (p. 348). It is characterized by the occurrence of phenocrysts of orthoclase or sanidine imbedded in a macroscopically dense groundmass.

Orthoclase (*sanidine*) occurs in idiomorphic crystals, tabular parallel to the clinopinacoid (010), which are often 20 to 30mm in their greatest diameter. These crystals are generally white and opaque, but occasionally clear and transparent ones occur.

One such orthoclase crystal which is cut nearly parallel to the clinopinacoid (010) shows the faces $0P$ (001), $+P\bar{\infty}$ ($10\bar{1}$), $+2P\bar{\infty}$ ($20\bar{1}$), ∞P (110), $\infty P\check{\infty}$ (010). The position of the optic axes and the size of the optic axis angle indicate that these crystals are sanidine. They are comparatively free from inclusions and where weathering has occurred it is shown by a kaolinization and consequent opaqueness of the crystals.

Eleolite appears only in the groundmass and is frequently

very indistinct. It resembles that described in the tinguáites of the Fourche Mountain region (p. 101).

Sodalite appears in small idiomorphic crystals and is characterized by its form and "dusty" appearance.

Ægirite is rare, but occasionally occurs in large idiomorphic crystals.

The *groundmass* consists of lath-shaped orthoclase or plagioclase crystals and innumerable minute, green crystals which are probably ægirite (See p. 283).

The ordinary accessory minerals are such as magnetite, apatite etc., and are usually present in but small quantities.

In the cases where the eleolite and the sodalite of the groundmass are present in only very small quantities this rock approaches closely the ægirite tinguáite group and cases may occur where no eleolite nor sodalite whatever is present and the rock forms a true ægirite tinguáite.

b. Dike type.

This type has been observed in but one locality (p. 348) and in that case the rock forms a reddish brown dike in which are bedded phenocrysts of orthoclase.

This rock was not examined microscopically, but it is probable that it is similar to the rocks of the same class which occur at Magnet Cove.

B. Augitic Rocks.

Among the augitic rocks there are some which differ slightly in appearance from the members of the monchiquite group already described elsewhere.

The first variety of these occurs in dikes cutting the limestone rocks as described (p. 347) and appears macroscopically as a dense black, rock in which are scattered, here and there, small, black crystals which, by the aid of a magnifying glass, are seen to have a prismatic habit. Under the microscope these are seen to be phenocrysts of augite lying in a groundmass containing smaller augites. These two

components, together with magnetite, make up almost the whole mass of the rock.

The *augite* is the typical form of basaltic augite and shows both a zonal and an hour-glass structure, twins parallel to the orthopinacoid (100) and an idiomorphic crystal form as in the individuals described under Fourche Mountain fourchites (p. 107) and in Chapter XII.

The second generation augites have the same pinkish yellow color as the phenocrysts and show the same cleavage-cracks and extinction angles. The younger crystals are usually proportionately more elongated in the direction of the vertical axis than the phenocrysts and both the twinning parallel to the orthopinacoid (100) and the zonal structure are wanting.

These crystals with an occasional, minute, broken flake of biotite and numerous grains of magnetite are the only minerals now visible in the rock. There are, however, irregular spots filled with decomposition products which appear as if they had at sometime been olivine, but the indications are so uncertain that olivine can hardly be considered to have been identified as an original component of the rock.

The *groundmass*, in so far as it has been observed, is perfectly isotropic and shows no tendency to devitrification. It is present in very small quantities, but when some of the powdered rock was boiled with hydrocholoric acid and the liquid evaporated to dryness on an object glass immense numbers of small cubes of salt were observed in the gelatinous silica formed. This indicates that the groundmass is alkaline in its constitution and can easily be decomposed by acids.

The second variety of monchiquite which occurs at Potash Sulphur Springs is interesting both because it shows a decided fluidal structure and because the augite crystals which were originally small have almost entirely disappeared and are indicated only by small, reddish brown, hexagonal spots (these are bounded by the faces 110 and 010) and long, monoclinic or rectangular sections which, only very rarely,

show any undecomposed material in their centers. This rock contains much secondary biotite and many decomposition products.

Still another variety of monchiquite is one in which the augite crystals are large and well crystallized, but have been so acted upon since their formation that in most cases they have been replaced by a light green, highly refracting material, which shows an extinction in the same direction as the augite, but whose extinction angle is much smaller. In this case also large quantities of secondary biotite may be observed.

III. CONTACT ROCKS AND MINERALS.

In many respects the contact rocks and minerals of the Potash Sulphur Springs region are similar to those of the regions already described, but in some ways they differ considerably from them.

One of the most important contact bands in this region is that which crosses the road leading from Lawrence station to Potash Sulphur Springs at a point about 700 yards (640m) south of the hotel (p. 348). It is formed by the intrusion of a vertical dike of eleolite syenite 30 feet (9.1m) wide, cutting the shales in a nearly east and west direction. The shale on both sides of this dike is of a greenish gray color and but little decomposed while the igneous dike has almost disappeared.

Near the line of contact the shale has entirely lost its shaly, laminated structure and has the appearance of a glassy igneous rock. It is cut by numerous small sheets and masses of pink and white minerals which present a strong contrast to the greenish color of the rock. It also contains numerous bands and masses of coarse-crystalline calcite.

Under the microscope the rock is seen to consist of pyroxene, plagioclase, quartz (scarce), wollastonite, and apatite.

Plagioclase forms a groundmass of small crystals which seldom exceed a millimeter in diameter and among these are scattered light colored, needle-shaped, monoclinic pyroxene crystals. The latter are usually very small, but are occasionally

as much as 2mm. in length. Their angle of extinction is about 15° and their pleochroism is slight.

The plagioclase crystals are quite distinct and form long, lath-shaped crystals which usually show twinning lamellæ and also occur as thick, broad crystals which do not show such lamellæ. The latter variety might easily be mistaken for sections of orthoclase, but it is probable that they are plagioclase crystals cut approximately parallel to the brachypinacoid (010).

Quartz appears only in a few, very indistinct, allotriomorphic individuals.

Certain long, narrow, colorless and semi-transparent crystal sections which are not truncated at the ends, but are frayed out and irregular, appear in the thin sections of this rock. They show sharp cleavage-cracks which make an angle of about 30° with the direction of the greatest dimension of the section. One such section remained dark between crossed nicols during a complete revolution of the stage. In convergent polarized light an interference figure appeared which consisted of a black cross and one ring. The character of the double refraction of this crystal is negative.

These crystals have a high index of refraction but only a a mediumly high double refraction. Smaller, needle-shaped crystals resembling the large ones occur plentifully in the section, but their form and appearance are quite unfamiliar to the writer.

Apatite occasionally occurs in minute needles.

Wollastonite occurs in the body of the rock in small, lath-shaped crystals, but its most interesting occurrence is in the form of the pink and white minerals which constitute the plates and masses already mentioned (p. 348).

The white variety of wollastonite occurs in slender columns and radiate masses. These are made up of crystals which are elongated in the direction of the *b* axis and show a cleavage parallel to the base (001) and the orthopinacoid (100). The cleavage-planes possess respectively a mother-of-pearl and a glassy lustre.

Under the microscope and in a polarized light the slender,

rod-like individuals have a parallel extinction and when observed in convergent polarized light a single optic axis is occasionally seen. By revolving the crystal vertically about its longest axis *b* another single optic axis is observed and it is evident that the plane of the optic axis is the symmetry-plane (010).

This white material is generally covered with a layer of the pink scales, described later, but by using sufficient care it can be completely separated from them.

A chemical analysis of this mineral was made by the Survey, R. N. Brackett, analyst, with the result given in the following table. An analysis of wollastonite from Mt. Vesuvius and the theoretical composition of that mineral and of xonotlite are placed beside this for the sake of comparison.

Analyses of wollastonite and xonotlite.

CONSTIUENTS.	I.	II.	III.	IV.	V.
	Wollastonite.			Xonotlite.	
	Potash Sulphur Springs.	Mt. Vesuvius.	Theoretical, $CaSiO_3$	Xonotla Mexico.	Theoretical $4CaSiO_3+aq.$
SiO_2	51.98	51 90	51.72	49.58	49.79
FeO	2.08	.....	.....	0.31	.....
CaO	42.55	46.44	48.28	43.56	46.48
MnO	2.08	0.96	.....	1.79	.....
MgO	0.44	0.65	.....	.....	.....
H_2O (ignition)	1.23	.....	.....	3.70	3.73
Total	100.26	99.95	100.00	99.94	100.00

I. Wollastonite (white), Potash Sulphur Springs; analyzed by R. N. Brackett.

II. Wollastonite, Mt. Vesuvius; analyzed by Wiehage (Mineralchemie, p. 379).

III. Theoretical analysis of wollastonite—$CaSiO_3$.

IV. Xonotlite (white) from Xonotla, Mexico; analyzed by Rammelsberg (Zeit. d. geol. Ges., Band XVIII., p. 33. Cited after Mineralchemie, p. 380).

V. Theoretical analysis of xonotlite—$4CaSiO_3+aq$.

It is evident from these analyses that the mineral in question is very near a wollastonite in its composition and that on account of the water which it contains it inclines

somewhat towards xonotlite. If, however, this water be disregarded (since it is in a great part hygroscopic), and the iron manganese, and magnesia be considered as replacing lime and the analysis then be recalculated to 100 per cent the following result is obtained, which for the sake of comparison is placed beside the theoretical analysis of wollastonite.

Analyses of wollastonite.

CONSTITUENTS.	Recalculated Potash Sulphur Springs.	Theoretical $CaSiO_3$
SiO_2	53.10	51.72
CaO	46.90	48.28
Total	100.00	100.00

From this comparison it appears that this mineral is an impure wollastonite which has undergone a slight decomposition and has taken up some water. Since it approaches the theoretical composition of wollastonite nearer than that of any other mineral and as it possesses all its crystallographic and optic characteristics it is considered as being an impure variety of that mineral.

The pink variety of wollastonite occurs in thin plates and scales. The color is apple-blossom-pink to pale rose color and is characteristic of the thin scales of this mineral. Some of this thin mineral was carefully separated from the white form and was analyzed by the Survey, R. N. Brackett, analyst, with the following results:—

Analysis of pink wollastonite (?)

SiO_2	50.96
FeO	1.69
CaO	36.72
MnO	1.40
MgO	0.57
K_2O	0.90
Na_2O	4.41
H_2O (Ignition)	2.74
Total	99.39

It is evident from this analysis that a part of the lime (CaO) has been replaced by soda (Na_2O) and that a slight weathering and a consequent increase in the amount of water (H_2O) has taken place. This gives the mineral an intermediate position between wollastonite (normal calcium silicate), xonotlite (hydrous normal calcium silicate) and pectolite (hydrous polysilicate of lime and soda). It might be considered as a xonotlite in which one-tenth of the lime (CaO) is replaced by soda (Na_2O) and in which the ratio of the normal silicate to the water is as 5 to 1 in place of 4 to 1 as in xonotlite. In view of this fact the name *natroxonotlite* is suggested for this variety. By recalculating this analysis and grouping the manganese, magnesia and iron with the lime and the potash with the soda the following analysis is obtained and is placed beside the theoretical analyses of wollastonite, xonotlite, pectolite and the percentage composition of natroxonotlite corresponding to the formula $5(\frac{9}{10}Ca + \frac{1}{10}Na_2)\ SiO_3 + aq$.

Comparison of analysis of natroxonotlite with theoretical composition and with wollastonite, xonotlite and pectolite.

CONSTITUENTS.	Recalculated natroxonotlite.	Natroxonotlite—5 (0.9 Ca+0.1 Na_2) SiO_3 + aq.	Wollastonite = Ca SiO_3	Xonotlite —4Ca SiO_3+aq	Pectolite— H Na Ca_2 Si_3O_9
SiO_2	51.65	49.91	51.72	49.79	54 22
CaO	40.49	41.96	48.28	46.48	33.74
Na_2O	5,08	5,15	.....	.....	9.33
H_2O	2.78	2.98	.....	3.73	2.71
Total	100.00	100.00	100.00	100.00	100.00

It is evident that this is an altered wollastonite in which soda and water have replaced some lime and not a pectolite in which only part of the soda is present, for the natroxonotlite is evidently a normal silicate and not a mixture of a bisilicate with a polysilicate as pectolite is believed to be. The natroxonotlite is formed by a decomposition of wollastonite while pectolite is considered a distinct mineral.*

* Mineralchemie, Rammelsberg, 1875, p. 881.

Another interesting occurrence of contact minerals is that in the bed of the creek directly west of the bowling-alley at Potash Sulphur Springs. This contact rock consists principally of a coarse-crystalline calcite which penetrates a metamorphosed shale and in some cases presents the appearance of having a perfect flow structure. It occurs in narrow seams and bands as well as in large masses and is often in direct contact with the igneous rock. In other cases it appears to pass gradually into an igneous rock, but it is probable that the latter is in such cases only a highly metamorphosed sedimentary rock.

This coarse-crystalline calcite contains but few metamorphic minerals. Pyrrhotite (magnetic pyrites) has been observed in masses which occasionally reach a centimeter or more in diameter. It is characterized by its magnetic properties, its bronze color and its softness (not over 4). It is without crystal form and is imbedded in the calcite. It readily decomposes and it is probably from this mineral that the potash sulphur water obtains its sulphuretted hydrogen.

In this same calcite bed about 30m (100 feet) up the stream (north) is a ledge or bed in which occur numerous idiomorphic crystals of orthoclase. These range from 1 to 4cm in diameter and are thick tabular parallel to the clinopinacoid (010). They are colorless and translucent to transparent and in many cases present a glassy appearance. The faces which have been observed are as follows:—

$\infty P\bar{\infty}$ (010), $\infty P\frac{3}{2}$ (130), ∞P (110), $0P$ (001), $+P\bar{\infty}$ (10$\bar{1}$) and $+2P\bar{\infty}$ (20$\bar{1}$) (indistinct).

The faces were much etched and roughened so that no good reflections could be obtained, but the following angles were measured by the writer:—

	Measured.	Calculated. (Dana).
(110) : (1$\bar{1}$0)	61° 30′ 80″ (poor)	61° 12′
(1$\bar{1}$0) : ($\bar{1}$30)	30 13	29 59
($\bar{1}$30) : (0$\bar{1}$0)	29 20	29 25
(1$\bar{1}$0) : (0$\bar{1}$0)	59 10 30	59 24
(001) : (0$\bar{1}$0)	89 48 (poor)	90 0
(001) : (010)	90 1	90 0

The cleavage parallel to the base (001) is very perfect and the cleavage-plates show a mother-of-pearl lustre. The cleavage parallel to the clinopinacoid (010) is much less distinct and the lustre is below that of glass. A third system of cleavage-cracks appears parallel to the right hand prism face l=(110) but no cracks are visible parallel to the corresponding left hand face T=(110).

The acute bisectrix makes an angle of 5° with the base (001) and lies in the obtuse angle β. A section at right angles to this bisectrix shows the plane of the optic axes at right angles to the symmetry-plane. The optic axis angle was measured in sodium light and gave an angle of 68°.

An analysis of this mineral was made partly by the writer and partly by R. N. Brackett,* chemist of the Survey, with the following result:—

Analysis of orthoclase from Potash Sulphur Springs.

SiO_2	62.82
Al_2O_3 (†)	19.08
CaO	2.17
MgO	trace
K_2O	8.99
Na_2O	5.92
H_2O	0.46
CO_2	1.23
Total	100.67

(†) Incl. a trace of Fe_2O_3.

It is evident from the amount of CO_2 present that some calcite is mixed with the feldspar material and consequently all the CO_2 and sufficient CaO to form $CaCO_3$ (calcite) were deducted from the analysis and the whole was again brought to 100 per cent with the following result:—

Recalculated analysis of orthoclase.

SiO_2	64.17
Al_2O_3	19.49
CaO	0.62
K_2O	9.19
Na_2O	6.05
H_2O	0.48
Total	100.00

* Dr. Brackett determined the alkalies.

The orthoclase is rich in soda and may be considered as made up of one molecule of sodium aluminium silicate combined with one molecule of potassium aluminium silicate for the Na_2O is to the K_2O in the exact proportion of 1 to 1.

The occurrence of this potash soda aluminium silicate in the limestone shows that alkalies are present in that rock and it may be that it is this and not the eleolite syenite that furnishes the alkalies which are contained in the potash sulphur water.

IV. POTASH SULPHUR WATER.

The water which has given the reputation to the Potash Sulphur Springs exudes from the calcitic rock in the bed of the creek and is collected in large drain-pipes imbedded vertically in the rock. The water rises in these pipes and is dipped out from the top as it is required. The strength of the water is said to vary with the quantity that flows from the spring. If the pipe be emptied and allowed to fill again the water is much more highly charged with sulphuretted hydrogen than it is if it remains some time in the pipe.

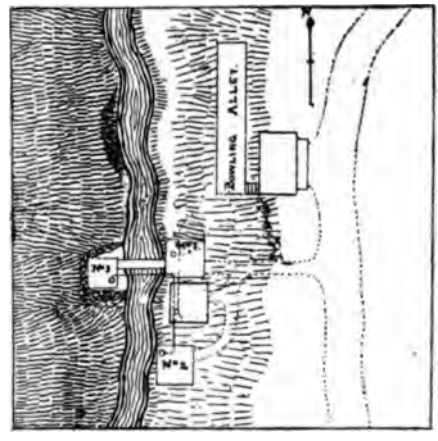


Fig. 42. *Sketch map showing location of the springs at Potash Sulphur Springs, Arkansas.*
Scale: 75 feet—1 inch.

Two complete analyses have been made of the water, but as they were not taken from the same spring but little agreement can be expected in the analyses. (See fig. 42.)

The analyses are as follows:—

Analyses of water from Potash Sulphur Springs.

CONSTITUENTS	GANNAWAY			CLARKE		
	FOUND			FOUND		
	Grams to the Liter	Grains to the U. S. Gallon	Per cent of total Solids	Grams to the Liter	Grains to the U. S. Gallon	Percent of total Solids
SiO_2	0.03270	1.9069	3.67	0.0275	1.6035	4.13
SO_4	0.38853	22.6506	43.65	0.2027	11.8194	30.43
CO_3	0.10926	6.3700	12.28	0.1458 (†)	8.5015	21.89
Cl	0.05238	3.0535	5.88	0.0405	2.3615	6.08
H_2S	Trace	Trace	Trace	None	None	None
Fe	0.00264	0.1541	0.30			
Al	Trace	Trace	Trace	0.0020 (*)	0.1166(*)	0.30(*)
Mn	Trace	Trace	Trace			
Ca	0.00836	0.1958	0.38	0.0032	0.1865	0.48
Mg	Trace	Trace	Trace	None	None	None
K	0.00683	0.3979	0.77	0.0227	1.3536	3.41
Na	0.29440	17.1633	33.07	0.2216	12.9214	33.28
Total solids	0.89011	51.8921	100.00	0.6660	38.8340	100.00
CO_2 (free)	0.04401	2.5660				
	HYPOTHETICAL COMBINATION			HYPOTHETICAL COMBINATION		
KCl				0.0433	2.5248	6.47
NaCl	0.08643	5.0386	9.72	0.0328	1.9125	4.89
Na_2S	Trace	Trace	Trace			
K_2SO_4	0.01520	0.8863	1.71			
Na_2SO_4	0.56258	32.7979	63.20	0.2988	17.4230	44.62
Na_2CO_3	0.17931	10.4535	20.14	0.2572	14.9973	38.42
$MgCO_3$	Trace	Trace	Trace			
$CaCO_3$	0.00840	0.4896	0.94	0.0080	0.4664	1.19
$FeCO_3$	0.00547	0.3193	0.62			
$MnCO_3$	Trace	Trace	Trace			
Al_2O_3	Trace	Trace	Trace	0.0020	0.1166	0.29
SiO_2	0.03271	1.9069	3.67	0.0275	1.6035	4.12
Total Solids	0.89010	51.8921	100.00	0.6706	39.0441	100.00
CO_2 (free)	0.04401	2.5660				

(*) Al is here calculated as Al_2O_3 (†) CO_3 by difference.

The first analysis was made for the Geological Survey of Arkansas in 1887 by C. B. Gannaway who collected the water in October of that year.

The second analysis was made for the U. S. Geological Survey during the fiscal year 1886 to 1887 by F. W. Clarke, chief chemist.

Gannaway obtained the water for his analyses from the spring (No. 3, fig. 42) on the west side of the creek while the water which Clarke analyzed was taken from the "original Potash Sulphur Spring" (No. 1, fig. 42) on the east side of the creek about 25 feet (7.6m) east of the former.

The constituents given as carbonates in the analysis made by Gannaway were calculated by him as bicarbonates, but they have been recalculated as carbonates in order to make the analysis comparable with that of Clarke.

The temperature of the water in the spring, as determined by Gannaway, was 64° F. (17.7°C.) A faint odor of sulphuretted hydrogen has observed.

The analysis made by F. W. Clarke, U. S. Geol. Survey, was first published in a bulletin * of the U. S. Geological Survey. In this analysis no attempt was made to determine the H_2S, for such determinations must be made at the spring. Clarke states that the amount of water which he had at his disposal was too small for a complete analysis.

R. N. Brackett, chemist of the Geological Survey of Arkansas, determined the amount of sulphuretted hydrogen (H_2S) in the water from the original Potash Sulphur Spring (No. 1), as follows:—

Amount of H_2S in Potash Sulphur Springs (No. 1) water, Nov. 13, 1890.

Grams in a liter	0.00157
Grains in a U. S. gallon	0.0890
Cubic centimeters in a liter	1.2
Cubic inches in a U. S. gallon	0.3

The temperature of the water was 16° C (61° F).

On account of the variation in the amounts of potassium

* Bulletin of the Geological Survey, No. 55. Report of work done in the division of Chemistry and Physics mainly during the fiscal year 1886-'87, Washington, 1889, p. 91.

and sodium found by Gannaway and Clarke, which is probably due to the fact that the water came from the different springs, Brackett redetermined them in water from the "original spring" (No.1) with the following results:—

Potassium and sodium in Potash Sulphur Water.

CONSTITUENTS	Grams in a liter	Grains in a U. S. gallon
K	0.06024	3.5122
Na	0.23432	13.6608
Total	0.29456	17.1730

These determinations were made with 250cc (2.1136 gills) of water.

These values agree much better with those of Clarke than with those of Gannaway, a result to be expected since Clarke and Brackett both analyzed water from the "original spring."

On account of the want of similarity in the amount of "total solids" found by Clark and Gannaway in the springs analyzed by them these were redetermined at two different times by R. N. Brackett and the amount of solid material in still a third spring (No. 2, fig. 42) south of the "original spring" was also determined twice. The result of all of these determinations are as follows:—

Solid matter in Potash Sulphur Springs.

ANALYST.	Date.	Spring No. 1.		Spring No. 2.		Spring No. 3.	
		Grams to Liter.	Grains to U. S. Gal.	Grams to Liter.	Grains to U. S. Gal.	Grams to Liter.	Grains to U. S. Gal.
F. W. Clarke	1887	0.6706	39.0441	.....	.....	.....	.....
C. B. Gannaway	Oct., 1887	.....	.....	.....	.....	0.89011	51.8921
R. N. Brackett(*)	July 11,1891	1.1322	66.0069	0.8522	49.6801	0.5353	31.0209
R. N. Brackett (†)	Aug. 3, 1891	0.8135	47.4160	0.8582	50.0299	0.4231	24.6651

(*)Water collected by J. H. Means, July 11, 1891.

(†)Water collected by C. E. Siebenthal at 3 p. m., Aug. 3, 1891, after a week of heavy rain. Spring No. 3 had been cleaned out during the morning of the same day on which the sample was taken.

It is evident from these few determinations that these springs vary extremely in strength from time to time and it would require a large number of observations under all conditions of weather and temperature to determine exactly what the causes of the variation are. The heavy rains before Aug. 3, 1891 appear to have perceptibly weakened springs Nos. 1 and 3, but do not seem to have affected No. 2 at all.

The most that can be said for the analyses given above is, therefore, that they represent the amount and composition of the solid matter in the particular springs from which the water was taken and at the time that it was collected.

V. RELATION OF THE IGNEOUS ROCKS TO EACH OTHER AND TO THE SEDIMENTARY ROCKS.

The relation of the igneous rock of the Potash Sulphur Springs region to each other are comparatively simple. The oldest rocks are the coarse-grained, granitic eleolite syenites. These occur in the form of large, intrusive masses and also as comparatively narrow dikes.

Both the larger masses and the dikes of eleolite sodalite syenite are bordered by tinguáitic bands of greenish or brownish rock which are distinctly porphyritic in appearance. It would be natural to expect an eleolite porphyry as the border type of this basic eleolite sodalite syenite, but instead of it an eleolite tinguáite, very poor in eleolite appears as a border rock. Dikes of a similar eleolite tinguáite occur in the sedimentary rocks and are probably contemporaneous with the larger syenite masses.

It is probable that after the intrusion of the eleolite rocks hot springs formed and deposited the calcite which often appears in cracks and fissures in the igneous rock itself. The apparent fluidal structure in the calcite in many of the cracks which are filled with it and its arrangement in bands parallel to the sides of other cracks indicate that the calcite was deposited after the intrusion of the syenite.

Both the igneous rock and the altered sedimentary rocks are cut by dikes of monchiquite and it is therefore evident that the latter were forced into cracks in the older rocks. It may be that the metamorphism which has converted the calcite into a

coarse-crystalline mass and which has produced the feldspar and other metamorphic minerals which it contains, is due to the intrusion of these monchiquite dikes.

No indications of igneous activity later than that of the intrusion of the monchiquite dikes have been observed and it is probable that no younger rocks exist in this region.

The relation of the igneous to the sedimentary rocks has been broached in the description of the metamorphosed rocks (p. 348). It is probable that the bending and folding and much of the erosion of the Paleozoic rocks was completed before the igneous rocks were intruded. Much erosion has taken place in this region since the igneous rocks were intruded and it has attacked both the sedimentary and igneous rocks.

The age, occurrence and subsequent history of these rocks are open the same arguments and consideration that applied to those of Magnet Cove (p. 343) for it is almost certain that the igneous rocks of this region are genetically identical with those of that region.

CHAPTER X.

SYENITIC DIKES AND ROCKS LYING OUTSIDE OF THE AREAS ALREADY DESCRIBED.

I. Ægirite Tinguáite Dikes.
   A. Hot Springs Dikes.
   B. Hominy Hill Dike.
II. Ash-beds and Detrital Material of Igneous Origin.
   A. Batesville Ash-bed.
   B. Polk County Ash-bed.

I. ÆGIRITE TINGUAITE DIKES.

These isolated syenitic dikes vary much both in size and structure, but they all appear to consist of the same minerals and to have been formed from similar magmas.

A. Hot Springs Dikes.

Location.—The most important of these both in point of size and on account of the possible bearing that it may have upon the origin of the famous Hot Springs of Arkansas is the one shown on map V. as beginning at Hot Springs* Creek about a mile below the city of Hot Springs and running in a nearly easterly direction for over half a mile and then disappearing. On the eastern side of the Middle Fork of Gulpha† Creek about a mile and a half from the end of the dike just mentioned, a similar dike of rock is found

* Hot Spring Creek appears to have been the name originally given to it, although it is now known as Hot Springs Creek.

† Also spelled Gulpher, Gulfer, Gulfa and Golfa.

which trends in the same general direction and would, if produced, fall almost in line with the former. It is probable that the two dikes were made by the filling up of the opposite ends of the same crack, but whether a portion connecting the two now detached sections ever existed is a matter of conjecture. It seems probable that if it did it would now show in the bed of the West Fork of Gulpha Creek, but neither the writer nor Mr. A. B. Aldrich,* a practical quarryman and contractor of Hot Springs, was able to discover any trace of it in the creek.

Occurrence.—The rock of these dikes as far down as they have been opened appears only in the form of huge boulders which become larger and more solid the lower the openings are cut. So far as is known, no perfectly solid rock has been found in any of the openings along the higher parts of the dike, but where the dike cuts the bed of the Middle Fork of Gulpha Creek it appears quite solid and compact. It is probable that the creek which has cut away the sedimentary rock to a point far below the level reached in the lowest pits on the hill has at the same time cut the dike down to a point which the weathering has not reached.

Previous notices.—The only literature notices of this rock consist of several newspaper articles written about the six or eight openings made in the dike by Mr. Aldrich and an indication of their location on a map entitled "Map showing health and pleasure resorts of the Ozark Mountains in and around Hot Springs, Ark., by H. M. Woolman, C. E."

Macroscopic characteristics.—The rock of the dikes present a bluish or greenish gray color and is variable in structure. In some parts it is macroscopically coarse-grained and trachytic in its appearance while in other places it is fine-grained and porphyritic in structure showing here and there large phenocrysts of feldspar. Like all the other grayish crystalline rocks it is commonly known by the name of

* The Survey is much indebted to Mr. Aldrich for many valuable suggestions regarding these syenite dikes as well as for his kindness in accompanying the writer in tracing them out and in searching for new ones.

granite although it in truth possesses very little likeness to a typical granite. It has been extensively used in Hot Springs for curbing, paving and foundation material.

Microscopic characteristics.—This rock is seen to be a porphyritic mixture of glassy feldspar (sanidine) and pyroxene, with a few small crystals of magnetite and titanite.

Feldspar (sanidine) occurs in two generations. The crystals of the older generation form large phenocrysts (1.5 to 2.0cm) in a fine-grained groundmass of feldspar and pyroxene. These crystals are tabular parallel to the clinopinacoid (010) and are about five times as long as they are wide. They are glassy and present externally in every respect the appearance of sanidine. They are comparatively free from gaseous or solid inclusions.

The angle of extinction, orientation etc., is as usual in sanidine. The plane of the optic axes usually lies parallel to the symmetry-plane (010) but in a few cases it has been observed at right angles to this. In neither case does the optic axis angle exceed 15°. The crystals are therefore sanidine and not orthoclase.

The feldspar of the younger generation consists of allotriomorphic crystals which with the pyroxene form the groundmass in which the crystals of the first generation are imbedded. The feldspar of the groundmass is usually fresh and transparent and like the phenocrysts belong to the variety sanidine. It some cases it has been somewhat decomposed and shows kaolinization and the formation of calcite.

The *pyroxene* consists principally of slender, light green prismatic crystals which are somewhat pleochroitic and have a small angle of extinction. These are *ægirite*. Besides these, thicker, larger crystals of pyroxene occur which are of a lighter green color and often show a tinge of violet. The pleochroism in these is hardly detectable. The angle of extinction is in the neighborhood of 40°. These crystals are

probably either *diopside* or some variety of pyroxene closely allied to it.

Amphibole and *biotite* have not been observed.

Eleolite or nepheline has not been observed.

Magnetite, titanite and *apatite* occur in small idiomorphic crystals, but are generally quite scarce.

A chemical analysis of this rock was made by the Survey, W. A. Noyes, analyst, and the results of the analysis (I) are given in the following table and are compared with those of an analysis (II) of ægirintinguáit from Norway.

Analyses of ægirite tinguáite.

CONSTITUENTS.	I.	II
	Ægirite tinguáite, Arkansas.	Ægirintinguáit, Norway.
SiO_2	54.07	56.58
TiO_2	0.15	.....
Al_2O_3	21.67	19.89
Fe_2O_3	3.55	3.18
FeO	.....	0.56
MnO	.....	0.47
CaO	0.36	1.10
MgO	0.36	0.13
K_2O	4.76	5.43
Na_2O	8.91	10.72
Ignition	5.44	1.77
Total	99.27	99.83

I. Ægirite tinguáite dike 1 mile (1.6km) south of Hot Springs, Arkansas; analysis by W. A. Noyes.

II. Ægirintinguáit, Asbjörnsröd, Hedrum, Norway; analysis by G. Paijkull (Syenitpegmatitgänge, p. 41).

The analysis of the rock from Arkansas shows by the high percentage of soda (Na_2O) that an eleolitic rock might have resulted had the conditions under which it was intruded been right for such a formation. It is probable that the feldspar is rich in soda (Na_2O) and as the ægirite contains

from 8 to 12 per cent of this substance the comparatively high percentage of soda (Na_2O) in the analysis is easily accounted for.

The rock might be called an ægirite syenite dike rock or an ægirite tinguáite and either name would express some quality of the rock which the other does not bring out, but the name ægirite tinguáite has been adopted to designate the rock of this dike.

It should be stated that the rock of this dike is not uniform throughout its whole width, but is much more porphyritic or tinguáitic near the contact with the sedimentary rock than it is in the center. Where the rock comes in direct contact with the shale, as it is seen to do in the old quarry on the east side of Hot Springs Creek, the igneous rock becomes a fine-grained tinguáite and the sedimentary rock resembles it so closely that even under the microscope it is a difficult matter to determine which is of igneous and which of sedimentary origin.

The contact between the two rocks can in most cases be determined from the fact that the two rocks separate easily from each other along that plane while in other directions they are tough and hard to break.

The tinguáite dike contains numerous inclusions of the sedimentary rock which have been so highly metamorphosed that they have entirely lost their sedimentary character and resemble fine-grained igneous rocks.

Several other dikes and masses of somewhat similar rock occur in the neighborhood, as for example, in 3 S., 18 W., sec. 6, S. E. corner (map V. dike 31), 3 S., 18 W., sec. 23, W. half (map I dike 47) and 3 S., 18 W., secs. 25 and 26 (map I dike 48). In most cases these rocks are more typically tinguáitic than that just described and as they approach Magnet Cove they become identical with those already described from that region (p. 201).

B. Hominy Hill Dike.

At Hominy Hill, General Garland's place, 1 N., 14 W.,

section 27, (see map I., dike 6) the State Geologist found a dike of syenitic rock whose existence was indicated only by loose boulders. These appeared to cover a width of about 250–325 feet (75 to 100m) and extend in an east and west direction for several hundred yards. The dike is situated 325 feet (100m) north of Gen. Garland's house and crosses the Litte Rock and Hominy Hill road 850 feet (250m) northeast of the house; it is surrounded by siliceous shales of Lower Silurian age which strike about N. 45° E. and contain the quartz veins which are so commonly found in these rocks.

The rock from Hominy Hill presents a very similar microscopic appearance to the syenitic dike rock from near Hot Springs and is like that to be considered as a form of tinguáite. It has a somewhat more decided green tinge in the gray color and is more uniformly fine-grained in structure. Numerous small crystals of feldspar are visible which seldom if ever exceed 2.5mm in length.

Under the microscope the rock is seen to be a fine-grained mixture of orthoclase, plagioclase and pyroxene, which latter is in many cases replaced by its decomposition products.

Orthoclase is in long narrow crystals which are usually very much decomposed.

Plagioclase is also present, but to a subordinate degree only.

Pyroxene has been to a great extent decomposed, but the fragments which remain are of a pinkish color and indicate that it was originally titaniferous. It is probable that it is *diopside* and that the ægirite which may have formally existed in the rock has all been destroyed.

The rock has decomposed in such a way that long, colorless needles of high refractive power and a small angle of extinction have formed in it. Although no cleavage could be observed except that parallel to the vertical axis of the crystal, the small extinction angle—not over 5°—and other considerations make it probable that the mineral is some colorless form of amphibole.

A great part of the rock is occupied by a green *chloritic substance* which gives the greenish color to the rock. Under

the microscope it appears of the same light green color and between crossed nicols it is almost isotropic. By revolving the stage a slight variation between black and dark bluish gray is observed. By means of a selenite plate this slight differentiation is increased quite perceptibly.

Calcite and other decomposition products are very common, and on the whole the rock is so badly decomposed that little or nothing can be made out of it, except that in a general way it belongs to the syenite (tinguáite) group.

A dike which is probably similar to the one just described is mentioned by Owen * in the following words:—

"On Lindsay's branch of the south fork of the Saline, near Mrs. Richardson's, granite was found in loose fragments." The writer has been unable to find this locality but it is probable that there would be but little additional information to be gained on the subject, for Owen appears to have made a diligent search for the rock in place.

Other dikes of a somewhat similar character are described in the general table in chapter XIII.

II. ASH-BEDS AND DETRIAL MATERITAL OF IGNEOUS ORIGIN.†

In several parts of the state beds of igneous material occur interbedded with the Paleozoic rocks.

A. Batesville Ash-bed.

One of the most important and conspicuous of these beds occurs in the Batesville manganese region‡ and is best exposed at the Meeker place, township 14 N., range 7 W., section 8, in the south half. It was first observed by Dr. Penrose and its description taken directly from his report is as follows:—"The contact bed is seen in place and varies from 6 to 15 inches in thickness, is a compact, bluish-green, earthy rock. It contains small siliceous nodules, an eighth of an inch to one inch in diam-

* Second Report of a Geological Reconnoissance of Arkansas, 1860, p. 108.

† These deposits are not represented on the maps because they have not as yet been traced out in detail, and to indicate the few places where they have been observed would be more misleading than to omit them altogether.

‡ For further details concerning this region see the description by R. A. F. Penrose, Jr., in the Annual Report of the Geological Survey of Arkansas for 1890, Vol. I., p. 128.

eter, and small crystals of iron pyrites. White specks, a sixteenth of an inch and smaller are scattered through it. The material is slightly calcareous and weathers into a brown or buff-colored mass, much softer than the original rock. Its relations to the overlying and underlying formations are shown in the accompanying section. The residual clay in the section is the product of decomposition, in situ, of the St. Clair limestone.

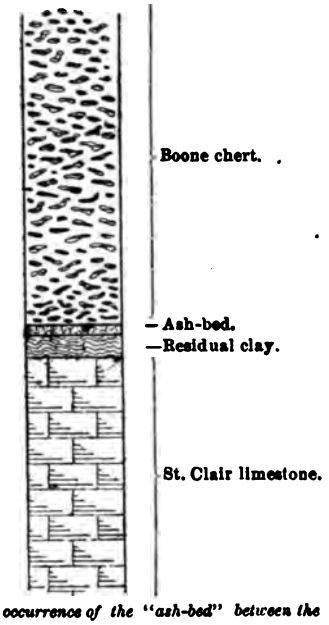


Fig. 24. *Section showing the occurrence of the "ash-bed" between the St. Clair limestone and the Boone chert at the Meeker place near Batesville, Ark* Scale: 1 inch—25 feet.

"Dr. J. E. Wolff, of Harvard University, has very kindly examined under the microscope a slide made from a sample of this material collected by the Survey and has found evidence pointing to the possibility of its being composed partly of volcanic ash, though, as he suggests, further laboratory work will be required to determine the matter definitely. He describes the section as composed of rather angular, small, clastic grains of quartz and of fragments of trinclinic feldspar, often much bent and rounded, and sometimes angular; together with deep brown, homogeneous grains which are partially transparent, but completely isotropic in polarized light. The latter show no signs of cleavage or crystal structure, and look like possible fragments

of a ferruginous basaltic glass. The clastic grains are separated by thin films of a green chloritic substance.

"Lack of time has not yet permitted a further investigation of this subject, but should this deposit, representing as it does the parting between the Silurian and Carboniferous terranes, prove to be an ash bed, it will throw additional light on the series of phenomena which took place in the interval between those ages. That the deposit is not of this nature everywhere in the region is shown by the fact that in many places, even in the neighborhood of the Meeker locality, it consists of what seems to be a common sedimentary sandstone though in some places the grains composing it show a very remarkable globular form.

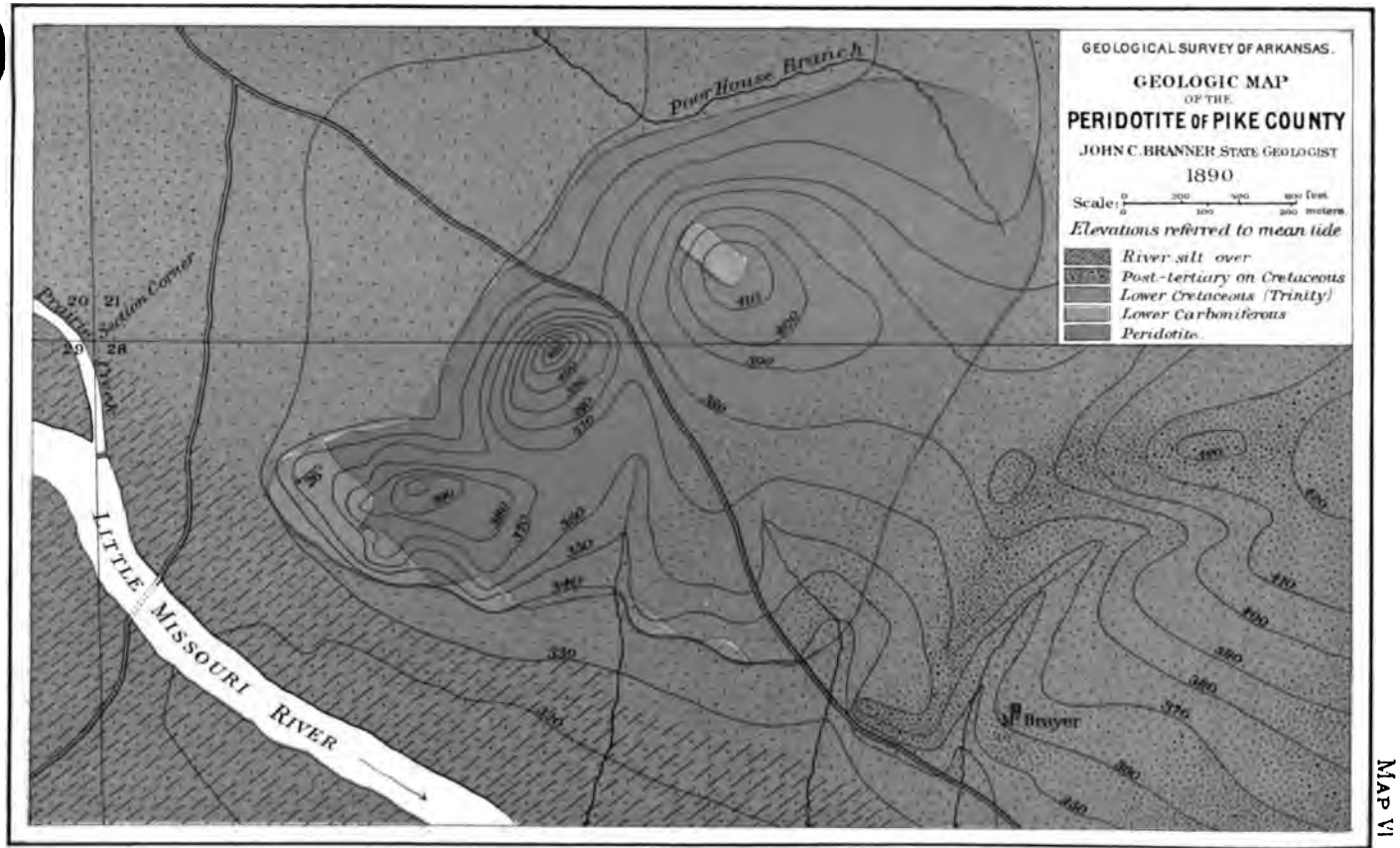
"Dr. J. C. Branner, State Geologist, had already suggested, from his examination in the field previous to the discovery of the above mentioned locality, that the parting between the Silurian and Carboniferous in northern Arkansas might contain eruptive debris, * * *.

The writer has never visited the locality described above, but the thin section which was studied by Dr. Wolff is in his hands and he can add nothing to the latter's description of the rock. No opportunity for studying the rock chemically or for making separations by means of heavy liquids has presented itself and until such an investigation has been made no additional light can be thrown upon the origin or character of the deposit.

B. Polk County Ash-bed.

In southwestern Arkansas between the Indian Territory border and the upper waters of the Little Missouri river a series of outcrops of rock containing much detrital igneous material occurs. These beds were first observed and noted by Mr. J. Perrin Smith of the Survey and were afterwards examined by Dr. R. A. F. Penrose, Jr. The writer has never seen the rocks in place and has studied them only in hand specimens and thin sections. Smith reports them in township 5 S., range 32 W., section 1, southeast quarter of northwest quarter, as forming a

low ridge, dipping steeply to the north and striking due east and west. They are interbedded with sandstones and shales following these in all their folds. Weathering has been very active with these beds and in most cases the rock appears only in the form of boulders from which little or nothing could be learned concerning its mode of occurrence. Penrose thinks that in some cases the beds may be as much as twenty or thirty feet (6.1 to 9.1 meters) in thickness.


GEOLOGICAL SURVEY OF ARKANSAS.
GEOLOGIC MAP
OF THE
PERIDOTITE OF PIKE COUNTY
JOHN C. BRANNER, STATE GEOLOGIST
1890
Scale: 0 200 400 600 feet. 0 100 200 meters.
Elevations referred to mean tide
River silt over
Post-tertiary on Cretaceous
Lower Cretaceous (Trinity)
Lower Carboniferous
Peridotite.
Poor House Branch
Section Corner
20 21 29 28
Prairie Creek
LITTLE MISSOURI RIVER
Brower

Map VI

CHAPTER XI.

Distribution and Petrographic Character of the Igneous Rocks from Pike County.

I. Distribution.
II. Petrographic and Chemical Characteristics.
III. Comparison with other Peridotites.
IV. Relations of the Igneous Rocks to the adjacent Sedimentary Rocks.

I. DISTRIBUTION.

In Pike county there occurs a small area of basic igneous rock* which has been so thoroughly studied and described † by the State Geologist and Dr. R. N. Brackett, chemist of the Survey, that little has been left for the writer to do, beyond copying the greater part of their work directly with such additions and changes as are necessary to make their article correspond with the other portions of this report and to bring it up to the present date.

Previous notices—The first mention of this region was made in a vague way by W. Byrd Powell‡ in 1842, who connected it genetically with the Fourche Mountain, Saline County, and Magnet Cove igneous areas.

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* This is shown on map VI.

† The peridotite of Pike County, Arkansas; by John C. Branner and R. N. Brackett Am. Jour. Sci., Series 3, Vol. XXXVIII., 1889, p. 50. With map which is reproduced as map VI. of this report.

‡ A Geological Report upon the Fourche Cove, etc., by W. Byrd Powell, M. D., 1842, p. 6, foot note.

It was then referred to by C. U. Shepard* in 1846, and a hand specimen of the rock which was sent to him by the Rev. E. R. Beadle was described in the following words:—

"From the same region (viz: Little Missouri, Pike County) section 27, 8 S., 25 W. A trachytic porphyry. It has the dry, harsh feel, and emits the peculiar odor (when moistened) of the European trachytes. It is said by Mr. Beadle to be as recent as the Tertiary."

It was next mentioned by D. D. Owen in his "Second Geological Report"† but was not studied by him in detail, and the rock is simply spoken of by him as a "porphyritic greenstone" and a "trachytic rock." Since Owen's time until the inauguration of the present survey of the state no one seems to have made any observations upon it. Some of the geologic maps of the United States, that have, from time to time, been published indicate in this place a large Archean area.

In 1889 Dr. J. C. Branner, State Geologist and Dr. R. N. Brackett, chemist of the Survey, published the paper entitled "The Peridotite of Pike County, Arkansas," referred to above and in it Dr. Branner describes the occurrence and distribution of the rock as follows:—

Occurrence—"Two and one half miles southeast of Murfreesboro, in Pike County, Arkansas, is a small exposure of peridotite whose position and topographic features are shown in detail upon the accompanying map.‡ The entire exposure is about 2400 feet long by 1600 feet wide, and lies upon the middle of the line between sections 21 and 28 of township 8 south, range 25 west.

"From a geological standpoint this exposure is an important one, for, small as it is, it offers a suggestion regarding the time and character of the disturbing influences, which, about the close of the Cretaceous, sank the greater part of Arkansas as well as the large Tertiary-covered portions of the neighboring states beneath the ocean.

Distribution and general characteristics of the rock.—"With

* Am. Jour. Sci. Series 2, Vol. II., 1846, p. 253, foot note.

† Second Report of a Geological Reconnoissance of Arkansas by D. D. Owen, 1860, p. 32.

‡ This is map VI of this report.

the accompanying map and section before the reader, it will not be necessary to give a detailed description of the locality. The rock presents no great variety in lithologic characters, and the specimens examined microscopically by Dr. Brackett, and described by him in the second part of this paper fairly represent them, except that in many places through the general mass it contains a good many angular and sub-angular inclusions of crystalline rock, which are especially noticeable wherever the rock is deeply decomposed, and that one small dike coming up through the Mesozoic beds contains a vast quantity of fragments of Paleozoic sandstone and shale and of a soft sandstone and quartz pebbles from the Mesozoic. Only in the three hills shown upon the map, and one very small dike is the rock found solid, disintegration having gone so far in the lower grounds that it there occurs only in the form of a soft earthy wacke, which washes very rapidly into deep gullies. This earth where freshest and unmixed with organic matter, presents many beautiful shades of green, brown, red, and gray colors. At one point a dike is uncovered in one of these gullies. This dike is about six feet wide, runs east-west, and in place of the olive-green color so characteristic of the general mass, it is of a beautiful bright blue color. It is so deeply decomposed that no solid specimens could be had from it. On the summit and sides of the central hill the rock mass is broken into large blocks, which, by concentric disintegration and exfoliation, are left in the form of boulders of various sizes.

"If the overlying Post-tertiary and Quaternary debris could be removed in the immediate vicinity of this exposure, it is probable that the area of igneous rocks, as shown upon the accompanying map, would be somewhat enlarged, at least by disclosing dikes radiating from the central mass. There is no reason for supposing however, that that the Post-tertiary obscures any great area of peridotite. There are no exposures of it in Prairie creek, except a single small dike not more than ten inches wide and about fifty feet long, while a deep gulley on the north side of the outburst (Poor House branch on the map), shows no exposures. East of the exposure at the house

of Mr. McBrayer (shown upon the accompanying map), a well recently dug to a depth of 162 feet penetrated only the clay, cobblestones and soft calcareous beds, such as characterize the Post-tertiary and lower Cretaceous in this region.

The following is the section of Mr. McBrayer's well:—

10′ Clays.....Quaternary and recent.

10′ Cobbles and pebbles..Post-tertiary.

142′ Soft arenaceous clays and calcareous beds variously colored. } Lower Cretaceous ("Trinity" of Hill).

"These facts appear to indicate that the outburst was confined to this very circumscribed area, there being no eastward extension of it at the depth reached in McBrayer's well—162 feet below the level of his house—and but one westward exposure uncovered at the mouth of Prairie creek."

II. PETROGRAPHIC AND CHEMICAL CHARACTERISTICS.

Brackett describes the petrographic characteristics of the rock as follows:—

"The specimen of eruptive rock from the middle hill shown in the map, consists in the main, of a dark colored somewhat green, heavy rock having a porphyritic structure, and specific gravity of 2.728 to 2.651. Examined microscopically it is seen to be made up of black grains, some slightly yellow and having glistening surfaces, imbedded in a dark green to brownish-green groundmass. The material from the base of the northeastern hill, is a brown, much decomposed rock, with a more distinctly porphyritic structure due to the decomposition of the black to yellow grains, and of the groundmass to a decided brown, against which the yellow grains stand out sharply. The specific gravity of this rock is 2.317. Through it extends a vein of white barite about four inches in thickness.

"In contact with the barite vein are veins of serpentine formed by the decomposition of the rock. In immediate contact with the barite the serpentine vein is white, but shades through a light green into the brown rock.

"A microscopic study of thin sections prepared from speci-

mens from the first exposure mentioned, reveals a rock of true porphyritic structure, consisting of crystals and grains of more or less decomposed, colorless olivine and some irregular patches of a yellow to brownish-yellow mica imbedded in a quite uniform, fine-grained groundmass made up of colorless little lath-shaped crystals, yellow grains, black grains and a yellowish base.

"The olivine crystals and grains are decomposed in the usual well known way, being cracked and changed to serpentine along the cracks. Few or none of the olivines are entirely unchanged, though there are many fresh cores and almost entire grains and crystals remaining. Where no olivine is left the outlines of the former olivine crystals are often well preserved. In such cases the olivines are entirely changed to serpentine, of both yellow and light green color and to carbonates, and hydroxide of iron, to which last the reddish stain of many is due. Many of the decomposed olivines contain also "trichites," slender, black, hairlike bodies which occur singly and in bunches. These "trichites" are probably magnetite.

"The yellow mica is grown through with little colorless lath-shaped crystals like those in the groundmass. It has a weak pleochroism; *O*=orange or faintly reddish. *E*=yellow.* In some cases the patches of mica are of a darker color and have a stronger pleochroism; *O*=brown; *E*=light brown, almost yellow.

"The colorless lath-shaped crystals that make up a large portion of the groundmass and penetrate the patches of mica, have an extinction angle as high as 45°, and many of them give lively polarization colors. From their association, appearance, optical behavior and close resemblance to similar crystals found in the groundmass of the Syracuse serpentine (to be referred to later), they are probably augite. They were so considered by Dr. G. H. Williams who has kindly examined a section of this rock.

"The yellow grains are scattered all through the groundmass, and are next in importance to the augites, and like them are an original constituent of the rock. They are highly refract-

* Determined by Dr. G. H. Williams, Johns Hopkins University. To Dr. Williams thanks are also due for kindness in examining a section of this rock, and for a specimen of the Syracuse serpentine.

ing, and stand out well in the slide. In color they range from colorless through yellow to yellowish-brown. In form, some appear as irregular grains, others are diamond-shaped or square. They occur singly or grown together in groups. Very many have crystalline planes and few or none of them are quite isotropic. They resemble very closely the yellow grains described by G. H. Williams * as occurring in the serpentine (peridotite) from Syracuse, New York, which he found by actual separation and analysis to be perofskite. J. S. Diller † described yellow grains in the peridotite from Elliott county, Kentucky, which they resemble, perhaps, more closely than they do those described by G. H. Williams. Diller at first took these to be anatase, but a subsequent separation and analysis showed them to be perofskite also. An unsuccessful attempt was made by the writer to separate the yellow grains by the method of Stelzner ‡ as recommended by G. H. Williams in his paper on Syracuse serpentine. But the identity in appearance of the yellow grains in the Pike county rock with those in the Kentucky peridotite which Diller found to be perofskite after this attempted separation was made, coupled with the fact that by Gooch's method § 0.89 per cent of TiO_2 was found in the rock, made it so probable that the mineral was perofskite, that no farther attempt at separation was made. The presence of perofskite here is interesting as being the third instance of its occurrence as a constituent of any American rock, the first instance being that reported by G. H. Williams in the Syracuse serpentine, the second that by J. S. Diller, in the peridotite from Elliot county, Kentucky. It is also interesting as occurring in the same type of rock as will be mentioned later.

"The black grains scattered in not inconsiderable quantity through the groundmass, are believed to be magnetite. The yellow base 'looks as though it had been a glass once and some of it is still isotropic, though most of it polarizes.'‖ A considerable amount of it is still isotropic and was found in other sec-

* Am. Jour. Sci. Series 3, Vol. XXXIV., 1887 pp. 140-142.

† Bulletin of U. S. Geological Survey, No. 38, 1886, p. 18.

‡ N. Jahrb. f. Mineral. Beilage. Bd. II., p. 392.

§ American Chemical Journal, Vol. VII., p. 283.

‖ Dr. G. H. Williams' description of this specimen.

tions. From its mineral composition and structure, then this rock belongs to the family of peridotites, and to the new type of picrite porphyry or 'kimberlite' of H. Carvill Lewis."*

A complete chemical analysis made by the Survey, R. N. Brackett, analyst, gave the following composition:—

Analysis of peridotite.

SiO_2	38.78
TiO_2	0.89
Al_2O_3	6.85
Fe_2O_3	8.83
FeO	1.99
CaO	3.88
MgO	26.34
K_2O	2.56
Na_2O	0.78
CO_2	0.14
Loss on ignition	7.85
H_2O at 100° C.	1.95
Total	100.84

Brackett then adds the following description of the brown rock exposed near the picrite porphyry:—

"The brown rock, of which there is an exposure not far from the picrite porphyry just described, shows in thin sections a similar prophyritic structure. But here all the olivines are changed to serpentine, carbonates and hydroxide of iron. The outlines of the olivine and the structure of the rock are generally well preserved, although no fresh olivine remains. A great many patches of mica, partially grown through with colorless, little augite crystals are present, and perofskite is abundant. The most striking characteristic of the rock is the almost total absence of augite in the groundmass. This absence of augite is rendered still more striking by the fact that in the Syracuse peridotite, which is no more decomposed than this rock, the augites in the groundmass are apparently as fresh as when they were first formed. The explanation of this probably lies in the fact that the patches of yellow base, some of which is quite isotropic,

* Rosenbusch, Mik. Phys., Vol. II., 1887, p. 519.

are much more abundant here than in the other rocks described, and, perhaps, the augites did not have a chance to crystallize out, being deposited as a glass. There seems to be no doubt from its general appearance that this is a portion of the same original rock mass as that before described, and probably so situated with reference to it at the time of formation, that the now brown rock crystallized more rapidly than the other portion of the eruptive mass, represented by the rock at the first exposure described.

"The dike of blue earthy material, already mentioned has yellow grains scattered through it. The nature of the original rock, which this blue decomposed dike represents, cannot be definitely determined. A thin slice shows a few fragments of brown mica, and sections composed entirely of serpentine, occuring for the most part in irregular veins, but occasionally showing the form of olivine, imbedded in a green to bluish-green groundmass, which appears to be partly serpentine and partly chlorite. The porphyritic grains are composed of white, yellow and greenish yellow serpentine. The arrangement of the serpentine and the olivine forms still preserved indicate that all the porphyritic, serpentinized sections were originally olivine. It is quite probable that the rock consisted once of olivine with a small quantity of biotite imbedded in a groundmass made up largely of glassy base consisting chiefly of olivine substance which has weathered to serpentine and chlorite."

III. COMPARISON WITH OTHER PERIDOTITES.

The peridotite from Pike county differs somewhat from the other American occurrences as is shown by both its mineralogic and chemical composition. On this point Brackett makes the following remarks:—

"Unlike the Kentucky peridotite it contains no enstatite, its pyroxenic constituent being augite. It contains no ilmenite, and in only one section was any garnet found, a single, small, pink piece, quite isotropic. The perofskite, especially, occurs in great abundance in the Pike county rock and here is undoubtedly original, while in the Kentucky rock it is believed to be secondary, arising from the decomposition of the ilmenite, and the

quantity is comparatively small. Finally the Kentucky peridotite contains much more fresh olivine than that from Pike county, and pyrope which is abundant in the former is rare in the latter. The Syracuse serpentine or peridotite, on the other hand is much less fresh than the Pike county rock, and while it contains augite in the groundmass, the augites are much less abundant, as are also the perofskites. This rock is in some respects a new type. There is total absence of a rhombic pyroxene, which occurs as such in Diller's rock, and is probably represented by decomposition products in the Syracuse serpentine."

Rhombic pyroxene is also characteristic of the picrite of the "Courtlandt Series".* This rock is described as "of a dark green color and of an even grain of medium coarseness." Macroscopically hornblende is prominent, but under the microscope pyroxene is found to be the more abundant constituent. The other minerals composing the rock are olivine and magnetite. Pyroxene is represented by colorless diallage and by hypersthene. The olivine is often quite fresh.

The chemical analysis of this rock given below also shows it to be different from Pike county rock.

In order to compare the chemical composition of the Pike county rock with that of the other occurrences the analysis given above is placed side by side with those of the other rocks as follows:—

Analyses of peridotite.

CONSTITUENTS.	I. Pike Co. Ark.	II. (Serpentine) Syracuse, N. Y.	III. Elliott Co. Ky.	IV. Elliott Co. Ky.	V. (Picrite) Peekskill, N. Y.
SiO_2	38.78	40.67	29.81	29.43	47.41
TiO_2	0.89	.....	2.20	1.48	.....
Al_2O_3	6.85	5.18	2.01	2.36	6.39
Fe_2O_3	8.83	.....	5.16	.....	7.06
FeO	1.99	8.12	4.35	9.06	4.80

*"The Peridotite of the "Courtlandt Series" on the Hudson River, near Peekskill N. Y., by Geo. H. Williams. Am. Jour, Sci., Series 3, Vol. XXXI., 1886, p. 36.

CaO	3.88	.....	7.69	6.94	14.32
MgO	26.34	32.61	32.41	31.66	15.34
K_2O	2.56	.....	0.20	0.65	1.40
Na_2O	0.78	.....	0.11	0.78	(dif.)0.69
CO_2	0.14	.....	6.66	5.65	.....
H_2O (total)	9.80	12.77	8.92	10.90	2.10
P_2O_5	.....	.....	0.35	Trace	.....
Cr_2O_3	.....	.....	0.43	0.14	.....
MnO	.....	.....	0.23	.....	.....
NiO	.....	.....	0.05	0.06	.....
S. (in sulphides)	.....	.....	None	0.20	0.49
SO_3	.....	.....	0.28	0.30	.....
Total	100.84	99.30	100.86	100.15	100.00
Specific gravity	.....	.....	2.781	2.697	3.20

I. Peridotite of Pike County, Ark. Analyzed by Brackett and Smith.

II. Serpentine from Syracuse, N. Y.* Analyzed by T. Sterry Hunt.

III. Peridotite† from Elliott county, Kentucky. Analyzed by T. M. Chatard. (Bulletin U. S. Geological Survey, No. 38, 1889, p. 18).

IV. Peridotite† from Elliott county, Kentucky. Analyzed by A. M. Peter and J. H. Kastle. (Ibid. p. 18).

V. Peridotite‡ near Peekskill, N. Y. (South side of Montrose Point) by W. H. Emerson (Am. Jour. Sci., Series 3, Vol. XXXI., 1886, p. 40).

IV. RELATIONS OF THE IGNEOUS TO THE ADJACENT SEDIMENTARY ROCKS.

In regard to the genetic relations of these rocks to the sedimentary rocks of the region Dr. Branner makes the following statements:—"Besides this peridotite, the rocks exposed in this part of Arkansas are of Paleozoic, Lower Cretaceous ("Trinity" of Hill), Post-tertiary and Quarternary ages. The Paleozoic rocks form the high lands of the hilly and mountainous region

* Am. Jour. Sci., Series 2, Vol. XXVI., 1858, p. 237.

This rock which Dr. Hunt obtained from Professor James Hall, of Albany, contained 34.77 per cent of carbonate of lime, 2.73 per cent of carbonate of magnesia and 62.5 per cent of serpentine, and it was this latter constituent that was analyzed.

† These are the rocks described by Diller. (l. c. p. 25).

‡ This is the picrite described by G. H. Williams (l. c. p. 26).

of the state lying north of the Neozoic exposures. They are made up of alternations of sandstones and shales, and are highly flexed, the axes of the folds varying but little from due east and west. Just north of Murfreesboro, and four miles from the exposure of peridotite, these sandstones and shales have a high south dip, at many places standing almost or quite vertical. These south dips continue for many miles to the north, a section measured across the beds farther east showing an aggregate vertical thickness of strata of at least four miles. Against and upon the eroded, upturned edges of these Carboniferous rocks the lower Cretaceous beds have been deposited. The rocks of the Cretaceous are soft sandstones, shales, lignites, clays, etc., all beautifully variegated, the predominating colors being straw, lead, pink, and terra cotta, and the beds exhibit a low and almost imperceptible dip to the east and southeast.*

"The Little Missouri River and its predecessor, flowing along the original inland margin of the Cretaceous, have here cut out a valley five miles wide, its right and southern wall being a line of nearly vertical Cretaceous cliffs, which are the attacked northern edges of these beds; the left or northern border

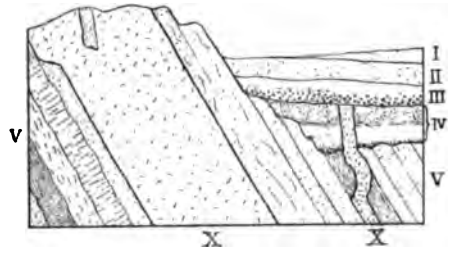


Fig. 44. *Section through the Pike County Peridotite and the adjacent Formations.*

I. River silt.
II. Yellow loam.
III. Post-tertiary.
IV. Lower Cretaceous ("Trinity" of Hill).
V. Paleozoic (lower Carboniferous?)
X. Peridotite.

is formed by the Paleozoic highlands, while the bottom of the valley is in lower Cretaceous beds covered by Post-tertiary debris and by Quarternary and recent sediments. It is in this

* Through the kindness of the Director of the U. S. Geological Survey, Prof. R. T. Hill spent the past year in studying the Mesozoic geology of Arkansas. His report forms Vol. II. of the annual report of the Geological Survey of Arkansas for 1888. In this report Prof. Hill shows that the Mesozoic rocks in the vicinity of this exposure belong to what he calls the Trinity, which he thinks is equivalent of the Wealden of Europe.

plane that the exposure of peridotite occurs. The accompanying section fig. 44 shows the relations of the intruded rocks to those of sedimentary origin.

" (The relations shown in this section, with the exception of the exact contact of the Paleozoic with the igneous rocks, may all be seen, though not at any one exposure).

"The contact between the Paleozoic and the Cretaceous is exposed in Prairie creek about two miles northeast of Murfreesboro where the Cretaceous rock is a conglomerate with calcareous cement. These parti-colored Cretaceous beds are cut into and exposed in many places, and at low water almost continuously, along Prairie creek from this point to the mouth of the stream, while on the right bank of the Little Missouri they rise in beautifully exposed cliffs to a height of nearly one hundred feet above the river.

" Where Prairie creek enters the Little Missouri, a dike of peridotite not more than ten inches wide stands out for fifty feet across the mouth of the former stream, and on the left bank of the river this dike is seen to penetrate the soft sandstones of the lower Cretaceous. Where the Cretaceous has been cut away by Post-tertiary erosion and covered with the water-worn debris, the dike is also cut off even with the eroded Cretaceous surface and covered with debris. At the line of contact between the dike and the Cretaceous sandstone, the most careful microscopic examination does not reveal the slightest trace of metamorphism. The original material injected into this crevice is so thoroughly filled with the debris of the beds through which it has passed—shales, sandstones and quartz pebbles—that their included fragments form about two-thirds of the dike as it now stands. Even the soft inclusions from the Cretaceous are unaffected. The great number of these inclusions suggest that the injected mass was cooled by them to such an extent that it was rendered incapable of producing contact metamorphism even on a very small scale.

" The horizontally bedded Cretaceous strata do not appear to be disturbed in any way whatever by the presence of this dike or even by that of the main body of peridotite. This little dike

affords the principal evidence in regard to the age of these igneous rocks.

"The Paleozoic exposure of this locality is the most southerly one known in the state. The rocks are all sandstones or quartzites, frequently false-bedded, and containing many so-called "fucoid impressions." They are much fractured and jointed and occur, for the most part, as irregular blocks, and only at the extreme southwest part of the exposure is it possible to determine their dip satisfactorily. The dip moreover is not uniform either in amount or direction, the one measured being 26° southwest, and somewhat below the average. The exact contact between the Paleozoic and the igneous rock is not visible.

"The rocks of this group vary considerably from flinty greenish quartzites to light-colored and porous sandstones, but this variation is no greater than one might expect to find in the variable sandstones of the Lower Carboniferous to which these are supposed to belong. Some of the quartzites are extremely hard, but the appearance of freshly broken specimens shows that this hardness is to be attributed to the indurating effects of weathering, rather than to contact metamorphism. In some instances the sandstones are of a light brown color and contain traces of vegetable matter, though no recognizable forms have thus far been discovered. In other cases they are tinged with green coloring matter, probably due to the presence of chlorite.

"Inasmuch as it has been suggested that the South African diamonds may have been generated by the metamorphism of the carbon in the carbonaceous shales penetrated by peridotite, it should be added that no such phenomenon is suggested by observations at this locality or upon these rocks.

"The Post-tertiary wash so widespread in southwestern Arkansas is thinly scattered about the foot of the ridge of peridotite. Its cobbles and pebbles are of sandstone, quartz, novaculite, and jasper, cemented here and there into a ferruginous conglomerate. The fragments are usually

much water-worn, but some of them are subangular, while in size they range from that of one's head downward. Careful search was made among this material for fragments of peridotite or serpentine, but none was found. From the readiness with which this rock decomposes, however, it could hardly be expected that such fragments would be preserved for any great length of time.

"The sum of our evidence favors the hypothesis that this peridotite is a simple injection which took place about the close of the Cretaceous through and between the Paleozoic strata, and penetrating the lower Cretaceous beds, and that whatever its relations to orographic movements may have been, it caused no great direct disturbance either chemical or physical in the beds with which it appears in contact.

"It naturally occurs to one that the Tertiary subsidence and the intrusion of these igneous rocks are associated in some way; but which is the cause and which the effect, the facts to be gathered at this locality do not indicate.

"The course of geologic events at this place as indicated by the geology of the region was as follows:

Time.	Event.
1. Close of the Carboniferous.	At the close of the Carboniferous, the rocks of that age were flexed, lifted, and subjected to very extensive subaërial erosion.
2. Early Cretaceous.	The southeast margin of the eroded land sank beneath the ocean and the lower and upper Cretaceous beds were deposited against and upon them.
3. Close of the Cretaceous.	The land was elevated and the Cretaceous beds exposed to a brief period of erosion.
4. Early Tertiary.	The igneous rocks were ejected through the Paleozoic shales and sandstones and the clays and soft sandstones of the lower (and upper?) Cretaceous, and the land sank beneath the seas in which the Tertiary beds were laid down.
5. Post-tertiary.	The Tertiary series was elevated and in the slow process of passing through the beach condition its soft beds were subjected to extensive erosion and denudation.
6. Quaternary.	Quaternary events, which need not be specified here.

"Of all the known occurrences of crystalline rock in the

state of Arkansas, the peridotite of Pike county offers the best evidence of the date of its intrusion. All the other known exposures are north of the Cretaceous area and in a region in which metamorphism has been so general that every trace of the paleontologic evidence of the age of the rocks penetrated that may have existed has been entirely obliterated, and we are therefore unable to determine by any evidence thus far collected, the precise age of those beds, and are consequently unable to determine the age of the eruptives."

It is evident from the above statements that the time of the intrusion of these rocks was not far removed from that of the syenitic and monchiquitic rocks in other parts of the state.

CHAPTER XII.

The Basic Dikes occurring outside of the Syenite Areas of Arkansas.

By J. F. Kemp.

Occurrence.—The explorations of the State Geological Survey have brought to light a number of basaltic dikes outside of the regions described by J. Francis Williams in the preceding chapters, as well as a number of others associated with the syenites of Magnet Cove and Saline county. Some of the former are situated as much as forty miles (65km) or more away from the principal masses of eruptive rock, while the latter penetrate, not only the strata quite near the disturbed area, in Saline county, on Teager Creek, and in the neighborhood of the Ouachita River, in Hot Spring and Garland counties, but are also developed in the ridges of Magnet Cove and in its interior basin, while those in the Saline county syenite district pierce the syenite itself. Even the rocks from the remoter dikes, as will appear in the descriptions, are closely related to those of the syenite centers and they are doubtless all genetically connected. It is not to be supposed that all or even a large proportion of them have been or can be discovered on account of the overlying soil, vegetation and limited exposures.

The dikes described here, as shown by the general tabulation in the next chapter, are very narrow. The widest one recorded and definitely determined is four feet (1.13m) while the average is from one to two feet (0.3 to 0.6m) and in some instances they are as narrow as one inch (25mm). They suffer so

severely from disintegration that only about one-third of those collected furnish sections sufficiently fresh to be available for accurate work, but by comparison with these the general character of many of the others can be determined. The wall rock where not eruptive, is either limestone, sandstone or shale. Where observations have been made on the dikes in sedimentary rocks they are usually found to be vertical.* D. D. Owen† mentions a locality near Mill Gap, Hot Spring county where the igneous rock appears to overlie the sedimentary. This place has since been visited by J. Francis Williams, who found that the igneous rock has simply forced its way between the strata of the displaced sedimentary rocks. It would appear from the prevailing vertical character of the dikes that, in general, the walls have not been much disturbed since their intrusion. Such specimens as were thought in the field to come from low-dipping exposures have proved, when examined microscopically, to be metamorphosed sedimentary beds. The macroscopic resemblance between the dikes and metamorphosed sedimentary rocks is often extraordinarily close. So far as can be noted the dikes produce little if any contact metamorphism in the walls. This lack of metamorphism is usually to be noted with narrow bodies of very basic rock.

Nomenclature.—The rocks here called ouachitites (pronounced wah'-she-tite) are named from the Ouachita River along which they are particularly well developed. They are considered as forming a new member in the monchiquite group lately proposed by Rosenbusch,‡ and as constituting a subgroup under the fourchite division of the latter proposed by J. F. Williams (see p. 110 of this report), and with which they are closely related, but from which they differ in mineralogic composition and, to a considerable extent, in geologic occurrence. The monchiquite group was formed to include the basic dikes of close affinities with the "tephrites, nepheline-rocks,

* Compare remarks by Geo. Englemann, Proc. of A. A. A. S., Vol. V., 1851, p, 199 cited in this report, chapter I., p. 13.

† Report of a Second Geological Reconnoissance of Arkansas by David D. Owen. Phila., 1860, p. 32.

‡ M. Hunter und H. Rosenbusch; Ueber Monchiquit, ein Camptonitisches Ganggestein aus der Gefolgschaft der Elæolithsyenite. Tschermak's Min. u. Petr. Mitth. XI., 1890, p. 445.

limburgites, camptonites and theralites",* but which have been found especially in connection with the eleolite syenite. They are subdivided on the basis of mineralogic composition as quoted in chapter IV. of this report, p. 109.

As will appear later, olivine is lacking or only very sparingly represented in almost all of the Arkansas dikes. The subdivision ouachitite is therefore made under the monchiquite and fourchite to include those rocks which lack olivine, but are rich in biotite and augite. This close affinity has been remarked by Professor Rosenbusch who has kindly examined a specimen from one of the freshest dikes and has emphasized its relationships. Ouachitite differs therefore from monchiquite much as a biotite-augitite does from limburgite and forms among the dike rocks a grouping similar to that adopted for the effusives.

In color the ouachitites are black or very dark gray. They are all porphyritic and exhibit very large phenocrysts of biotite and augite. Many contain both, but in some the former recedes, while in others the latter becomes less important. The augite may be 15 to 20mm in its greatest dimensions but averages less. The crystals are stout prisms and not tabular. The biotite in some cases measures as much as 25mm across the base and 15mm in thickness, but also average less. To macroscopic observation it is the most striking mineral in the rock. On a rough estimate its great phenocrysts make up about fifty per cent of the rock of dyke 18, but this is an extreme case. The augite and biotite when large stand out in bold relief. Such extremely large phenocrysts in such narrow dikes form a striking feature of these rocks. Even when the dike is as narrow as 25mm the the phenocrysts of augite are about 6mm across. In the dikes which occur long distances from what are regarded as the eruptive centers and so far as can be seen, remote from any notable parent mass, this occurrence of large phenocryste is very remarkable and, although not so very uncommon, is one of the most striking attributes of such basic dikes.

Microscopic examination.—Under the microscope the dikes are shown to consist essentially of augite, biotite, magnetite and

* Ibid. p. 447.

smaller amounts of a colorless, isotropic substance or glass. With these components are found in one case (dike 8) brown basaltic hornblende, in several others altered olivine and in a few instances titanite. Pyrite is common in the decomposed specimens. Apatite has been everywhere noted and in almost all specimens secondary calcite shows the beginning or advance of alteration. Although the glassy basis has some strong nephelinitic characteristics, only in one or two instances has definitely crystallized and anisotropic nepheline been detected.

In two instances a very feebly refracting mineral was noted which afforded between crossed nicols six-sided cross-sections of marked zonal structure very like fig. 2, pl. XIV., of Rosenbusch, Mik. Phys. Vol. I. It is probably some member of the sodalite group exhibiting optic anomalies analogous to the rhombic dodecahedral type of garnet. Haüyne is cited in the Portuguese dikes by van Werweke*.

The *augite* is of the basaltic type and occurs in two generations. It is often the most abundant constituent of the rock and marks a tendency towards a fourchite. The larger and older generation is formed of idiomorphic crystals of comparatively large size as noted above. They are almost always zonal and shade from lighter, well-nigh colorless tints inside to much more deeply colored rims. The interior may be faint green, yellow or reddish violet, the exterior deeper yellow or reddish brown. Pleochroism is occasionally present, but is not always noticeable. In dikes 207 and 232 it passes from faint green parallel b and a to red parallel c; in dike 60 yellow to light yellow. In dike 36 an augite with a colorless core and a reddish-brown rim showed an extinction of 41° for the former, 49° for the latter. This is the natural change from augite low in iron and colorless to one higher in the same and tinted. Titanite is probably present in the reddish or violet ones. The usual twinning on $\infty P\bar{\infty}$ (100) occurs but is not frequent. A zonal arrangement of included magnetite appears in dikes 8 and 36, but it is not very marked. Biotite is at times included, as usual, with $0P$ (001) parallel c of the augite, but such inclusions are not very common. In-

* Neues Jahrb. für Min. Jahrg. 1879, p. 451.

cluded apatite is rarely found and, indeed, the augite is on the whole rather free from foreign matter of all sorts; no glass whatever was remarked in any instance within its boundaries. It also seems to resist corrosion for while the biotite bears frequent evidence of having been resorbed, in only one instance did an augite show such a tendency. Tests before the blow-pipe failed to show the presence of sodium. Augites of the second generation appear as small, green prisms 0.05mm to 0.1mm and not so well bounded as those of the first generation. They are uniformly green and non-pleochroic as is usual in rocks of basaltic affinities.

The process of alteration seems at times to involve the formation of nests of small, olive-green hornblende prisms which replace the large augite crystals. Calcite is also a secondary product, as is shown by the effervescence of the interior of many crystals when treated with acid. The final result seems, however, in most cases to be the formation of a chloritic mass with limonite and calcite intermingled. Lines of some dark, ferruginous substance running regularly through such material seem at times to outline the position of old cleavage cracks, and it is probable that some of the iron oxide of the original bisilicates separated along these cracks.*

The *biotite* is of a rich, reddish brown tint, in sections parallel $0P$ (001). The crystals are large and well developed, but they have suffered much from corrosion and often show rounded contours which faintly suggest the original hexagon. Some irregular fragments also occur which are probably due to the position of the section. Somewhat rarely a second generation can be determined. Faint zonal structure is occasionally seen. The pleochroic colors change from deep reddish brown to faint yellow and are in great contrast. A slightly inclined extinction on $0P$ (001) is to be seen—perhaps of 2° or 3°. In some cases (dike 36), there is a notable divergence of the optic axes, but it probably does not exceed 5°. Attempts to determine the percussion figure failed, as the mica seems to have become too soft and yields little else than a hole. The position of the plane of the optic axes

* Compare Kemp, J. F., "Forest of Dean Camptonite" where a similar phenomenon is noted for hornblende. Am. Jour. Sci. Series 3, Vol. XXXV., p. 331.

parallel to the plane of symmetry, as determined by the crystallographic form, proves it to be normal biotite. It is very free from inclusions of all sorts, but augite has certainly been noted buried in a mica crystal (dike 18). Mechanical strains are to be seen, but are not frequent.

In alteration calcite and limonite form abundantly and the mica bleaches out. Such a whitened core may at times be seen buried in the surrounding calcite, chlorite, limonite and dirt, which its outer part has yielded. The irregular or rarely octahedral grains of magnetite exhibit few, if any, evidences of being highly titaniferous. To test this on a large scale a sample of dike 36 was crushed and concentrated* and the residue of a few grains thus obtained, consisted of the small heavy minerals from about one pound of rock. An ordinary magnet was found to remove all the magnetite and nothing but very perfect, small, hexagonal prisms of apatite and fragments of augite remained. From this it would seem that the titanium shown by the analysis I. is probably in the bisilicates.

The *glass basis* is not especially abundant, but appears at times forming masses of some size. It contains great numbers of extremely minute, colorless augite microlites. Larger crystals of augite of the second generation bristle into the glass from its boundaries in almost every instance, and give it the appearance of filling an interstitial space. This glass is much the same as that described by Bücking† as basis of the second kind, that is, it is colorless and when fresh gelatinizes readily with hydrochloric acid and is stained red with fuchsine.

This tendency to gelatinize with acids is doubtless a characteristic feature of these dikes. In alteration the glass affords abundant calcite and for this reason it is not often that

* This was done in accordance with the method recommended by O. A. Derby (see Proc. A. A. A. S., Indianapolis, 1890), which is as follows :—Crush the rock in a mortar and pass it through a 20 mesh screen. Then concentrate by panning with a low-coned copper pan in the way practiced by the Brazilian gold seekers.

† H. Bücking, Basaltische gesteine aus der gegendsüdwestlich von Thüringer Wald und aus der Rhön. Jahrb. d. k. p. g. Landesanst. für 1880, also the same for 1881.

the basis is fresh enough to gelatinize and stain. Bücking comments on the strong likeness between such a magma and that of the typical nephelinites.

At times hexagonal contours can be seen in the basis marking the formation of nepheline and possessing extremely faint double refraction.

Among the *accessory minerals* titanite appears but rarely and has nothing remarkable about it. Pyrite exists in irregular masses in the decomposed dikes. It is doubtless a result of alteration. Olivine has been noted in several dikes. It marks a tendency toward a true monchiquite and a thin section of dike 60 resembles strongly sections of the typical Brazilian rock.

In dike 3 abundant basaltic hornblende appears. The augite remains normal in amount, but the biotite decreases in quantity, still being present, but subordinate. The hornblende is in sharply defined idiomorphic crystals and makes a very beautiful section with the zonal augite. Its extinction angle is high for hornblende of this variety, and reaches at least 15°. It may be regarded as replacing the biotite to some extent and marking a deviation from the normal type and creating a tendency toward an amphibole-ouachitite or non-feldspathic camptonite. Such rocks have been noted elsewhere in dikes associated with eleolite-syenite *, but it is a noteworthy fact that similar dikes in other districts contain hornblende with greater frequency.

In macroscopic and to a large degree in microscopic characteristics the rock from the dikes, rich in biotite, has the strongest imaginable resemblance to the alnöite or melilite basalt of the Norwegian eleolite syenite areas. Specimens could be found practically indistinguishable (macroscopically) from alnöite sent to J. F. Williams by Professor Rosenbusch, but in no Arkansas dike has any melilite been found.

Chemical investigation.—An analysis of the rocks afforded the per cents given in the following table:—

* See Rosenbusch, Massige Gesteine pp. 795, 797, also the paper on monchiquite referred to above and literature subsequently cited.

Analyses of augitic rocks.

CONSTITUENTS.	I. Ouachitite. Hot Springs, Ark.	II. Ouachitite, Arkansas.	III. (Camptonite) New Jersey.	IV. Monchiquite Brazil.
SiO_2	36.40	38.07	40.47	46.48
TiO_2	0.42	.....	.....	0.99
Al_2O_3	12.94	17.92	11.86	16.16
Fe_2O_3	8.27	14.08	17.44	6.17
FeO	4.59			6.09
CaO	14.46	11.70	16.80	7.35
MgO	11.44	8.87	3.10	4.02
K_2O	3.01	2.23	4.21	3.08
Na_2O	0.97	0.96	1.90	5.85
H_2O	2.36	5.50	3.60	4.27
CO_2	3.94			0.45
P_2O_5	1.04	.....	.....	.....
Total	99.84	99.33	99.38	100.91
Specific gravity	.....	2.928	3.102	2.723

I. Is of dike 18 which is found four miles southwest of Hot Springs. (3 S., 20 W., sec. 11., N. E. quarter of N. W. quarter.)* The analysis was made by Mr. L. G. Eakins in the laboratory of the U. S. Geological Survey and kindly furnished to the Geological Survey of Arkansas by Prof. J. S. Diller.

II. Is of dike 4 (1 N., 15 W., sec. 33., N. E. quarter). This appears under the microscope to be one of the least altered of those collected. It contains less biotite than many others, but this mineral is replaced by augite. The biotite does not form over ten per cent of the rock. Analysis by J. F. Kemp.

III. Is of an analogous rock, which occurs with the eleolite syenite at Beemerville, N. J. Analysis by J. F. Kemp. (Am. Jour. Sci. Series 3, Vol. XXXVIII., p. 130.)

IV. Is of a Brazilian dike. Analysis by M. Hunter, (Ueber Monchiquite etc. Tscherm., Min. u. Petr. Mitth. XI., 1890, p. 454).

From these results it appears that the rocks are extremely basic, high in alumina and ferric and ferrous oxides, lime and magnesia, and low in alkalies. The excess of potash over soda is due to the abundant biotite, or conversely, it is possible that the presence of potash in excess may have caused its formation

*This locality was afterwards visited by J. F. Williams of the Geol. Surv. of Arkansas and the above mentioned dike was accurately located by the aid of Col. D. C. Rugg of Hot Springs.

and engendered one of the chief pecularities of the rock. Although analyses of such dikes, elsewhere, (see subsequent mention of literature) are not as yet generally available, the descriptions would indicate that biotite is much more subordinate than in the specimens from Arkansas. The rock from New Jersey, whose analysis is given above, in mineralogic composition approaches the nearest to these rocks. The New Jersey rock would have been described under some such name as is here employed, if as much had been known and recorded then as now.

Occurrence of similar dikes elsewhere.—It is a curious fact that dikes of very basic rock are commonly associated with eleolite syenite wherever the latter has been recorded and studied. Thus as far back as 1850, Bonnet * in a description of the occurrence of the eleolite syenite or foyaite of the Serra de Monchique in Portugal mentions basalt and melaphyre as associated with it, by which we are to understand simply a dark, basic rock. A series of specimens was subsequently collected there by Dr. Reiss and among these was one called basalt which occurred in dikes in the eleolite syenite. This came into the possession of Leopold van Werweke and in 1879 a description was published by him †. He determined the rock to be a limburgite and to consist of a gray groundmass with microscopic phenocrysts (Einsprenglinge) of hornblende, augite, olivine and haüyne. The hornblende is abundant, the olivine and haüyne, which among themselves are present in about equal quantities, less so; the augite is sparing; apatite is present. L. van Werweke states that it departs from the normal limburgite, but not enough to make a separate group.

A year later van Werweke again wrote on the Portuguese rocks more in detail.‡ He refers to the dikes already described and mentions another in the nepheline (eleolite) syenite of

* Bonnet. Algarve, Description géographique et géologique de cette Province. Ouvrage apprové et imprimié par l' academie royale des sciences de Lisbonne. Lisbon, 1850,

† L. van Werweke, Beitrag zur Kenntniss der Limburgite. Neues Jahrbuch, 1879, p. 451.

‡ L. van Werweke. Ueber den Nephelin-Syenite der Serra de Monchique im Südlichen Portugal, und die denselben durchsetzenden Gesteine, Neues Jahrbuch, Jahrg., 1880, Band I., pp. 141-186, especially p. 179.

Picota which he determines to be a nepheline basalt with accessory plagioclase. It is a finely crystalline rock and consists of idiomorphic hornblende, needles of augite, magnetite and magnesia-mica in a colorless, doubly refracting groundmass. With this are "microporphyritic" augite, olivine, and small rods of feldspar in the groundmass. The groundmass gives a grayish blue interference color, gelatinizes and yields cubes of salt on drying and is therefore called nepheline. The hornblende, augite and nepheline are about equally abundant. The magnetite is titaniferous. The augite is zonal, being gray inside with a red rim. The biotite occurs with magnetite in wreaths surrounding the olivine and is also subordinate in the groundmass. The syenite in which these augitic dikes occur has been shown to be later than the Culm and van Werweke pronounces these dikes to be different from any known pre-Tertiary type. Another specimen (p. 182) from the Valle do Bispo is pronounced nepheline basalt and is shown to consist of a fine-grained groundmass of nepheline, augite, olivine and much magnetite and mica. This one may not differ materially from the Arkansas dikes. A six-centimeter dike (p. 182) from Sitio das Rebolas has the same groundmass as the last with augite, amphibole, feldspar and mica phenocrysts. Another from Sitio do Barocco is prophyritic containing augite, feldspar, hornblende, mica, titanite and olivine. The hornblende phenocrysts are often as much as 6cm in length. The mica is subordinate. The augite is pleochroic, violet to yellow.

These Portugese rocks furnish some close parallels to the Arkansas dikes, but the general absence of hornblende and olivine and the extreme abundance of biotite in the latter, places them in strong contrast with the former.

O. A. Derby * has recently found basaltic dikes associated with the Brazilian eleolite syenites. Dikes of various kinds of basalt occur near Campo Grande in gneiss (p. 458). Again the gneiss at Tinguá is cut by small dikes (p. 459). In the Pocos de Caldas (Hot Springs) region tephritic basalts are associated

* Derby, O. A., On Nepheline Rocks in Brazil, etc., Q. J. G. S., London, 1887, p. 457.

with Carboniferous rocks. This appears to be very like the Arkansas dikes and Mr. Derby, who has looked over the slides of the Arkansas rocks in the Cornell laboratory with the writer, pronounces them to be very like the Brazilian varieties and to differ from the latter only in the greater amount of biotite which they contain.

A series of the Brazilian rocks was sent to Prof. Rosenbusch and by him entrusted to F. Fr. Graeff *, but nothing especially in regard to the dikes has as yet been published by him.

Very recently the paper by Hunter and Rosenbusch † cited above has appeared and, while in the main, it is intended to establish the general connection of these basic dikes with eleolite syenites, it gives a very full description of those from Brazil. Their many points of affinity with the Arkansas dikes have already been commented on.

As the result of field work done years before, the existence of a great dike of some eruptive rock near Beemerville, in northwestern New Jersey, was noted in the New Jersey report for 1868, p. 144. This was visited in 1881 by B. K. Emerson and a description was published in 1882.‡ Emerson mentions some stray pieces of a fine-grained, brownish black eruptive rock filled with scales of mica, which show nepheline in the thin section. Other bodies in place are mentioned in the New Jersey Annual Report for 1882, p. 67, and these led the writer (J. F. Kemp) to visit the region in 1888 and to study them in the field. As a result a description|| was published, but since the rocks are almost always excessively altered and impregnated with calcite it is difficult to determine what their original condition was. They were shown, however, to consist of abundant large crystals of biotite, of rather less frequent idiomorphic augite in two generations, of magnetite and apatite, and of some plagioclase, which

* Graeff, Franz, Fr., Mineralogisch-petrographische Untersuchung von Eläolite-syeniten von der Serra de Tinguá. N. Jahrb. für Min., Jahrgang, 1887, Band II., p. 222.

† M. Hunter and H. Rosenbusch, Ueber Monchiquit, ein Camptonitisches Ganggestein aus der Gefolgschaft der Eläolithsyenite. Min. u. Petr. Mitt., Band XI., 1890, p. 455.

‡ Emerson, B. K., On a great dike of Foyaite or Elæolite-Syenite cutting the Hudson River Shales in northwestern New Jersey. Am. Jour. Sci. Series 3, Vol. XXIII., 1882, p. 302.

|| Kemp, J. F., On Certain Porphyrite Bosses in northwestern New Jersey. Am. Jour. Sci. Series 3, Vol. XXIII., 1889, p. 130.

could be distinguished in the groundmass. The writer was unable to satisfy himself of the presence of nepheline, although strongly suspecting it, and hence from the Paleozoic surroundings of the rocks they were called porphyrites. It must be admitted that the age of intrusion of the syenite cannot be definitely stated and that all that appears is that it is later than the Hudson River and Oneida stages. The great basicity of the rocks, as shown by analysis makes their affinities with the porphyrites improbable and, as certain of the slides show the strongest analogies with the Arkansas dikes, all these rocks clearly belong in the same category. Prompted by the preparation of this paper the writer again visited the New Jersey region and spent nearly a week in field work. Several new outcrops of the basic rock were found and it was clearly seen to be associated with the eleolite syenite and to have come out on the eastern side of it, either close alongside or penetrating the shales a mile or two away. That other dikes of somewhat different character occur six or seven miles away will be shown in a later contribution. So far as can be judged the dikes or bosses in the neighborhood of the syenite are nearer like the Arkansas dikes than any rocks yet discovered.

In 1885 J. E. Wolff announced in the Neues Jahrbuch (Vol. I., of 1885, p. 69) certain nepheline rocks of great interest from the Crazy Mountains of Montana and subsequently published a detailed description of them.* The rocks form dikes in Cretaceous sandstone and consist usually of augite, biotite, nepheline, plagioclase, magnetite, olivine and haüyne. They appear to have considerable in common with those described above, as for example, the large augites and biotites whose mineralogic properties are closely related to those described here. But there are other differences, such as the presence of plagioclase and the fact that the rocks, so far as known, are not associated with eleolite syenites.

In the report of the Geological Survey of Canada for 1863†

* Wolff, J. E., Notes on the Petrography of the Crazy Mountains and other localities in Montana Territory. Northern Transcontinental Survey.

† Acknowledgments are here made to Mr. F. D. Adams of McGill College, Montreal, for a very kind reply to inquiries respecting these rocks and for several specimens for comparison. In thin sections the specimens sent are not very like the Arkansas dikes and resemble more closely *typical camptonites*.

p. 665, T. S. Hunt mentions, of course with no microscopic descriptions, as occurring near Montreal, trachytes, phonolites, diorites and dolerites. In the report for 1877–78, p. 429, B. J. Harrington adds an analcite-bearing rock or teschenite to the above. These rocks have since been investigated by Harrington and Adams and further descriptions are to be expected. Rosenbusch mentions (Massige Gesteine p. 90) the occurrence of eleolite syenite near Montreal. A. Lacroix has printed a note in the Comptes Rendus for June 2, 1890, p. 1152, entitled, "Sur la Syenite elæolithique de Montreal (Canada) et sur les modifications de contact endomorphes et exomorphes de cette roche." Lacroix mentions as cutting Trenton and Chazy limestones, hornblende and mica diabase and olivine gabbro, which contain at times enough nepheline and sodalite to occasion a passage into teschenite, in the sense of Fouqué et Lévy. After these basic rocks the eleolite syenite was formed and both are cut by narrow dikes of what are called porphyrites, including mica porphyrites, augite mica porphyrites (cf. New Jersey), hornblende porphyrites, augitites, and finally nephelinites with ægirite and secondary zeolites. Of these dikes, nothing further than mere mention is made, except that rolled boulders of them are found in a neighboring Lower Helderberg conglomerate, a fact that helps to fix the age of their formation.

For two seasons the writer under the auspices of the U. S. Geological Survey has been engaged in studying and mapping the dikes which occur very abundantly around Lake Champlain 40 to 100 miles (64 to 160km) south of Montreal. These are mostly diabases, camptonites and non-feldspathic monchiquites. In the southern portion of this area, the camptonites are chiefly found, while to the north are the monchiquites. These may in all probability be regarded as an outlying manifestation of the eruptive activity which had its chief development at Montreal and as furnishing another illustration, if this view be a correct one, of the distance to which such a manifestation may extend. On Lake Champlain they are 60 to 100 miles (96 to 160km) and more south of the main eruptive area. Quartzless and quartz porphyries (Bostonite?) occur with them in great development.

The Montreal area is being studied by Harrington and Adams from whom future detailed descriptions may be expected as stated above.

Eleolite syenite is known at Litchfield, Me., and at Salem, Mass., and the entire New England coast in this region is seamed with dikes * but as they are widespread and abundant and the eleolite syenite very subordinate, it would hardly be justifiable to connect all or, with our present knowledge, even a few of them with it. Such relations may, however, appear in the future.

Brögger mentions in his recent, exhaustive monograph† on the minerals of the Norwegian syenite pegmatite dikes, that dikes of basic rock occur which are the youngest of the series. He mentions (p. 79) diabase, diabase-porphyrite, proterobase, and proterobase-porphyrite. These rocks are more fully described in his earlier work: Die Silurischen Etagen 2 and 3, where they are said to be rich in plagioclase.

Dikes called originally melilite-basalt by Törnebohm ‡ were announced in 1882 from the island of Alnö and vicinity and likewise occur in close relation to eleolite syenite. The melilite rock has since been named alnöite by Rosenbusch. Its close resemblence to ouachitite has already been emphasized.

Greenstone dikes are casually mentioned in one of the papers on the Ditro eleolite syenite, cited by Koch|| but are not described. So far as is known to the writer, they are yet to be recorded from the Greenland area, for Vrba makes no reference to such dikes.§

The nepheline and melilite rocks from Greenland described by Törnebohm¶ were from loose blocks of which the field relations have not yet been definitely stated.

* Kemp, J. F., Dikes near Kennebunkport, Me.; American Geologist, March, 1890. Citations to the local literature are given.

† Brögger, W. C., Die Mineralien der Syenitpegmatitgänge der Sud-norwegischen Augit- und Nephelinsyenitgänge. Published as Vol. XVI., of the Zeitschr. f. Kryst., 1890.

‡ Cited from the original Swedish in Rosenbusch, Physiog. der Massigen Gestein, pp 304 and 309.

|| Koch, A., N. Jahrb. Mineral. Jahrg., 1880, Band I.

§ Vrba, K., Beiträge zur Kenntniss der Gesteine Sud-Grönlands, Sitzungsb. der Akademie der Wissensch. zu Wein. LXIX., 1874, I.

¶ *Cited from the Swedish in* Rosenbusch, Physiographie der Massigen Gesteine, p. 788.

From this widely distributed and well-nigh universal association of very basic rocks with eleolite syenite we must infer that there is some underlying genetic relation between the two. The syenites appear in most cases to precede, but this is not always true in Arkansas, and in New Jersey the relative age is not apparent. It is, to say the least, a striking phenomenon that two such sharply contrasted magmas should occur in such close proximity, the one being so subordinate in amount to the other.

Rosenbusch* attributes the occurrence of these widely different rocks to the splitting up of what he designates as the foyaite magma.

The work of collecting specimens and noting the occurrence of the dikes lying outside the syenite areas was done by J. C. Branner, E. C. Buchanan, T. B. Comstock, L. S. Griswold, R. A. F. Penrose, Jr., J. P. Smith, R. A. Whitmore, J. F. Williams and Arthur Winslow. Those within or very near the syenite areas were gathered principally by J. F. Williams, under whose charge the work has been. Most of the thin sections have been made and the petrographic investigation done in the Geological Labratory of Cornell University, Ithaca, New York. Seventy-five sections were made in all, ten of which were prepared by Dr. R. N. Brackett of the Geological Survey of Arkansas.

* Ueber die chemischen Beziehungen der eruptivgesteine by H. Rosenbusch. Mineral- und Petrograph. Mittheil., Band. XI., 1889, p. 144.

CHAPTER XIII.

Tabulation of the Dikes of Igneous Rock of Arkansas, by J. F. Kemp and J. Francis Williams.

This tabulation presents in a condensed form the chief points of interest concerning the occurrence and the more important petrographic characteristics of the dikes of igneous rock in Arkansas.

The dikes are arranged in a geographic order beginning with that one which lies furthest north and then proceeding southward taking each range of townships and considering under each of these first those lying at the extreme west and then those further to the east until all in that range of townships have been discussed. The only exceptions to this rule, that have been made, occur in cases where the dikes are represented on the special maps; in such cases all the dikes on one map are kept together regardless of the township in which they occur.

The fact is here again emphasized that this table contains, and from the nature of the case can only contain, a small proportion of the dikes which exist in the state. As far as these are at present known to the survey they are here tabulated.

The columns need very little explanation additional to that given in the headings, but attention is called to the following points:—

After dike 57 the column in which the township and range are given is omitted for in all the special maps no two sections of the same number occur and no confusion can arise from the *omission* of township and range.

After the same number of dikes the column, in which is recorded the name of the man who first reported the dike, is omitted, for all of the dikes (with the exception of dikes 58 to 64 inclusive, in which cases the fact is especially noted in the "location" column) were found and described by J. Francis Williams.

The column containing the name of the man by whom the microscopic petrographic descriptions of the several rocks were made contains a large number of blank spaces, showing that in those cases no microscopic examination was made and that the petrographic character and name of the rock were determined macroscopically by the finder.

As compactness is an essential in such a table, the descriptions of localities, occurrence and petrographic characteristics have been made as short as possible, and in some cases the clearness may have suffered from too great brevity in description.

The insertion of the small cuts in the "location column" has been made in order to express more easily and concisely than could be done in words the relative positions of the dikes in the banks and cliffs in which they occur. The cuts are to be considered simply as diagrammatic representations of the positions of the dikes, and are of such a nature that the actual appearance of the face of the cliff has in most cases had to be modified in order to bring out the points desired.

The punctuation has been omitted from the table, partly for the sake of compactness and partly from the fact that ordinary fonts of type do not contain punctuation marks in sufficient quantities to allow of their proper use in this large table. The omission of periods after single initial letters will cause but little confusion, but in the description of localities and especially in the petrographic descriptions the substitution of commas for colons and semicolons, and the entire omission of the commas from the sentences where they are necessary to bring out the sense may, at first, occasion some confusion, but if the fact of these substitutions and omissions is born in mind no misconception of the meaning need arise.

No. of Dike.	No. of map.	Township and range.	Section and quarter.	NOTES ON LOCATION AND EXTENT.	Width.	Strike.	Dip.	Wall rock.	Reported by.	Petrography by.	PETROGRAPHIC PECULIARITIES AND CONDITION OF ROCK.	Name.
1	I A	5 N 16 W	17 NW	.....	3′	.....	.....	.....	Winslow & Buchanan	Kemp	Mostly calcite, some zonal augite; considerable biotite, large crystals of apatite affording microchemic reactions.	Ouachitite
2	I	1 N 17 W	26 SE	On Perryville and Camden road 1½ miles N of Alum Fork.	5′	.....	.....	Shale and sandstone	Penrose	"	Rather altered but recognizable, contains large biotites, occurs in boulders 3′ to 4′ in diameter	"
3	I	1 N 16 W	32	On a hill back(?) of M'Allister's mill, overlain by blue dolomite.	.....	.....	.....	.....	Comstock	"	Containing hornblende; idiomorphic zonal, rose-colored augites with yellow borders, included peripheral magnetite, abundant idiomorphic brown basaltic hornblende 10° extinction, subordinate biotite, apatite small, isotropic base, secondary calcite.	Amphibole fourchite
4	I	1 N 15 W	33 NE	Exposed in spring at head of gorge and again in another gorge 150 W of first. Both gorges lead down to Cane Creek Dike traced 600 feet.	15′	E & W	Vert.	.....	R A Whitmore of Tatumville Ark	"	Augite zonal, idiomorphic and also of second generation, biotite subordinate, isotropic gelatinizing base stains well.	Ouachitite
5	I	"	10 SE	N of Geo. Wilson's house, near steatite quarries of Saline Co.	.....	.....	.....	.....	"	.....	Reported to be the same as dike 4. No specimen seen.	Ouachitite?
6	I	1 N 14 W	27	Near Gen. Garland's, Hominy Hill, Ark. See p. 371 of report	250′	E & W	.....	Siliceous shale	Branner	Williams	Boulders of a much decomposed rock with granitic (?) structure. See pp. 371 to 373 of this report.	Ægirite tinguaite
7	I	1 S 22 W	23 SW of SE	On a small stream flowing south. Similar rock reported to occur ½ mile west and also ¾ mile east of this place. (The information is too meager and the rock to difficult to distinguish macroscopically to give this report much value.)	4′	.....	.....	Shale	Smith	"	Syenitic rock much decomposed and containing much calcite, intruded into gray shale which has a low north dip.	Syenitic dike (Tinguaite)
8	I	"	26 NE	Near the house of Dunc. Bradley 1¾ miles N W of Cedar Glades P. O.	.....	.....	.....	Black limestone	"	"	Occurs in large boulders. Has similar appearance and mineral composition with dike 7.	"
9	I	"	"	50 ft E of dike 8. Exposed on S side of stream.	3′	.....	.....	Met. shale	"	"	Much decomposed, like dike 7.	"

10	I	1 S 22 W	26 NE	50 ft E of dike 9. Exposed in bed of stream.	6"	N 20° E	Vert	Met. shale	Smith	Williams	Much decomposed, like dike 7. In carbonaceous shale which has cindery appearance where it is in contact with the dike.	Syenitic dike (Tinguáite)
11	I	"	7 W half	One mile N. of Budd Lamb's house on Cedar Glades-Little Rock road. Outcrop 300 ft N of Snyder's shaft.	.....	.....	.....	.....	Smith	.....	.....	Ouachitite?
12	I	1 S 20 W	Line 30 & 31	On the line between sections 30 and 31.	.....	.....	.....	.....	"	.....	.....	"
13	I	1 S(?) 20 W	32	Described by Owen as on the South Fork of the Saline and in 1 N 17 W. The South Fork of the Saline does not run through that township and it is probably a mistake for 1 S 17 W. (See Owen's Rep't p. 108)	.....	.....	.....	.....	Brooks and Cox	.....	Called trap in Owen's report page 108.	
14	I	"	30	"On Lindsay's branch of the South Fork of the Saline near Mrs. Richardson's" (Owen's Report p. 108). This locality has been looked for but it is difficult now to determine which one of several branches was at that time called "Lindsay's Branch." The rock mentioned by Owen was not found but similar rock was discovered in the region.	.....	.....	.....	.....	"	.....	*A* Reported as boulders of granite Owen p 108. *B* Reported as "a black crystalline, overlying basaltic rock * * conformable with and insinuated between layers of argillaceous slate and a black calcareous rock difficult to distinguish externally from the basaltic rock itself." Owen page 108.	Syenitic dike Ouachitite? or Fourchite?
15	I	1 S 15 W	SW of 30	On Williams' Creek 300 ft south of "wire road."	40'	NNW	80° SSW	Shale	Williams	.....	Wide dike of heavy black rock with small mica crystals in it.	Ouachitite
16	I	2 S 20 W	32 SW	Phœnix Tunnel, 150 ft (?), ends in this dike. The igneous rock does not appear on the surface Regarding tunnel see Vol. I., Report Geo. Surv. Ark. 1888.	3' +	E & W	60° W	Quartzite	Griswold	Kemp	Idiomorphic zonal first generation augite, small green second generation augite, biotite up to 1" clearly biaxial, serpentinized olivine, magnetite.	Biotite monchiquite
17	I	"	1 SW of SW	On the Wildcat road near Jesse Robbins', dike visible in road and bed of small stream flowing west.	2	SE	80°E 35°N	Shale	Smith	Kemp	Altered but recognizable, idiomorphic augite and altered biotite. In dark gray shales dipping 30° N and 30° W.	Ouachitite
18	I	3 S 20 W	11 NE of NW	300 feet N of Maple Spring on Hot Springs-Bear road. Appears in steep bank.	4'	NW	Vert	"	Williams	"	See page 399 of this report for full description and analysis.	"
19	I	"	.....	Two miles little south of west from Thornton's ferry over Ouachita River. On the west side of river near Jerry Skegg's house.	.....	.....	.....	.....	Smith by report	.....	.....	"

20	I		W	.....	2 miles (+) SW of Gardner's ferry over Ouachita River.	.....	.....	.....	.....	Williams by report	.....	.....	Ouachitite
21	"	"		.....	Near mouth of Little Mazarn.	.....	.....	.....	.....	"	.....	.....	"
22	V	2 S	19 W	20 NE	Bed of East Fork of Bull Bayou ¾ mile above Hot Springs pumping station.	2'	NE	Vert	Sandstone	Williams	.....	Large biotite crystals.	"
23	"	2 S	18 W	30 NW	Half mile E of Dripping Spring 200 ft N of middle fork of Gulpha Creek. Traced several hundred feet.	3'	N 75° W	"	Shale	Griswold	.....	Decomposed to clay containing biotite and feldspar. Perhaps a metamorphosed sedimentary bed.	" ?
24	"	3 S	19 W	5 SE of NE	On west side of Central Avenue Hot Springs, 200 feet N of south line of city limits. Appears in low bank.	4'	E & W	.....	"	Jenny	.....	Much decomposed, biotite in reddish clay.	"
25	"	"		5 NE of SE	Small spot showing on west side of road 400 ft south of dike 24.	1' ?	.....	.....	"	Williams	.....	Biotite in dense black rock	"
26	"	"		4 SE of NW	In house lot of Mr. Calhoun on Malvern ave, Hot Springs, 200 ft S of Grand ave. Shows in bank W of house. Dike has too much north in its strike to unite with dike 24.	3'—4'	W to NW	Vert	"	Jenny	.....	Much decomposed, biotite up to 20mm comparatively fresh.	"
27	"	"		4 NE of SW	Dike cut through by new road along the east bank of Hot Springs Creek. At the highest point above creek. About 500 feet south of Grand avenue Hot Springs.	4½'	E & W	"	Sandstone	Williams	.....	Much decomposed, biotite up to 30mm comparatively fresh.	"
28	"	"		9 NE	For description of location see page 367.	10'	E N E	"	Shale.	"	Williams	Syenitic dike described on p 369 of report.	Ægirite tinguaite
29	"	"		2W¼ of NE	On Middle Fork of Gulpha Creek 1,600 ft N of H S R R.	2'	NW	"	"	"	.....	Dense black dike showing no macroscopic biotite nor phenocrysts of any kind.	Fourchite
30	"	"		2 & 1 N ½	See page 368 of report.	10'-40'	N 80° E	"	Sandstone	"	Williams	Syenitic dike described on page 369 of report.	Ægirite tinguaite
31	"	3 S	18 W	6 SE of SE	Forming steep hill NW of junction of E fork of Gulpha with small stream from the north. Scattered about on top of hill but forming part of bank of Gulpha.	10'-50'	NE	"	" ?	"	.....	Syenitic dike of decided green color and made up principally of trachytic feldspars and ægirite, seldom contains decided phenocrysts.	"
32	"	"		17 W ½ of NW	Dike directly W of bowling alley Potash Sulphur Springs. Location described on p 347 of rept	6"	NW	.....	Met shale contact calcite	"	Williams	Dense greenish black rock. Described on page 352 of report.	Fourchite
33	"	"		"	About 3 ft south of dike 32 and nearly parallel to it.	18"	NW	.....	"	"	"	Dense greenish black rock. Described on p 352 of report, same as last but contains more biotite.	"

4	V	3 S 18 W	17 cent S ½	In bed of east branch of Potash Sulphur Branch, see p 348 of report, ½ mile from its junction with Potash Sulphur Br'ch	3'	E & W	Vert	Shale	Williams	.....	A brownish tinguáitic rock. See p 352 of report.	Eleolite(?) tinguáite
35	"	"	17 SE of SW	In same stream as dike 34, ¼ mile further south. East of Dr. Lawrence's house about 600 ft.	18"	"	"	"	"	.....	Dense black rock, showing few phenocrysts of augite. Cuts through shale which lies almost horizontally.	Fourchite or Ouachitite
36	I	4 S 20 W	Cor 11,12,13, 14	At head of mill-race, ½ mile SW of Johnson's mill on upper Arkadelphia road along the Fourche á Loup Creek, exactly at section corner.	4 to 6	"	Horizon to 30°	Black shale	Branner	.....	Black rock containing large crystals of biotite.	Ouachitite
37	"	3 S 19 W	28 SE	South bank of Ouachita River below Roulston's ford.	.....	.....	.....	.....	Comstock	.....	Contains biotite.	"
38	"	"	35 or 36	Scattered boulders N side of Hot Springs-Malvern road, via Hot Springs Creek and Roulston's ford, 3 miles from ford. Traced boulders 300 ft.	5'	E NE	.....	Sandstone	Williams	.....	Boulders of black rock containing large biotites.	"
39	"	3 S 18 W	20 NW	In north bank of 2d railway cut ½ mile E of Lawrence station, H S R R. Intruded into bedding of shale and faulted near E end. 100 ft long.	3'	.....	N 10°	Shale	"	.....	Much decomposed but shows that it was intruded between strata. Thins out at E end beyond where it is broken by small slip or fault.	"
40	"	"	21 NE	In south bank of railway cut 2 miles E of Lawrence station, H S R R. Perhaps extends to N side of cut.	4'	S E	80° S W	"	"	.....	Black rock showing some large biotite crystals. Bands of altered shale on both sides. Rock weathered to rounded masses ½ to 1 ft in diameter.	"
41	"	"	"	Same bank, dike 50' further E.	3'	.....	20° S W	"	"	.....	No biotite appears, no metamorphism of shale.	Fourchite?
42	"	"	22 NW	In bank on N side of H S R R 3 miles E of Lawrence station. W of Price's station. Three dikes in same cut.	4'	E & W	45° E	"	"	.....	Contains no biotite Much weathered appears as boulders imbedded in decomp. material	"
43	"	"	"	Cuts dike 42 nearly at right angles 10 ft below surface, shows in face of cut.	2'	N E	35° N W	"	"	.....	Fresh rock containing biotite and showing metamorphic bands on both sides 6" wide. Contains biotite although not very plentiful.	Ouachitite
44	"	"	"	Narrow mass of rock lying in bedding of shale 50 ft E dike 43.	"	N & S	.....	"	"	.....	Much decomposed; shows no biotite; weathered to round boulders.	Fourchite?
45	"	"	22 NE	800 ft E of railway bridge over Teager Creek in cut on a curve	1'	.....	.....	"	"	.....	Much decomposed but probably contained biotite.	Ouachitite
46	"	"	23 NW	150 W of Teager Creek on H S R R on first curve.	"	.....	.....	"	"	.....	Decomposed beyond recognition.	" ?

47	I	3 S 18 W	23 W ½	Comes to H S R R 125 ft west of Teager Creek and extends S nearly half way to Ouachita River.	20′	N & S	.....	Sandstone	Williams	.....	Consists of boulders of green tinguaitic rock with large phenocrysts of sanidine.	Ægirite tinguaite
48	"	"	25 & 26	Dike appears S of novaculite ridge S of large curve of H S R R E of Cove Creek and runs in a southerly direction but turning gradually to E until it has a due easterly direction. It ends 1,000 ft W of the mouth of Cove Creek.	30′	S to E	.....	"	"	.....	Similar in every way to dike 47.	"
49	"	"	.....	Mass of mica rock reported on Slunger Creek which flows into Ouachita from SW nearly opposite Teager.	.....	.....	.....	.....	" (J. F. Moore)	.....	Contains large flakes of "black isinglass" (biotite).	Ouachitite
50	"	3 S 17 W	31 SW of SW	In bank of small branch on S side of a novaculite ridge lying S of Ouachita River due S from mouth of Cove Creek. Branch flows W and then cuts through ridge and flows N into Ouachita.	3½″	N 10° E	Vert	Novaculite	Griswold	.....	Decomposed to clay in which are imbedded flakes of biotite.	"
51	"	"	Cor. 29, 30, 31 & 32	Numerous dikes on S side of Ouachita River due S from Diamond Jo quarry. Some in bedding of shale others across it. Dikes so confused that all are numbered together.	.....	.....	.....	Shale	Williams	.....	Contain various amounts of biotite, sometimes very rich in it and again almost free from it	"
52	"	"	Line 29 & 32	Another group of dikes 200 ft further east. Owen reported one of them (p 32) as "a short distance above Mill Gap" and as dipping 10° to 11° and interbedded with shale. Page 15	.....	.....	10° etc	"	Owen	.....	Contain biotites in varying quantities as dike 51. See also Owen's description on p 32 of his report (quoted on p 15 of this report.)	"
53	"	"	29 SE of SE	Cut on H S R R S of Magnet Cove 30′ W of small stream which enters Ouachita River at the bend where it approaches closest to railway.	2′	.....	Vert	"	Williams	.....	Much decomposed; consists now only of clay with occasional biotite plates.	"
54	"	"	"	300 ft SE of dike 53 on NE side of railway.	"	.....	75° SE	Shale and Sandstone	"	.....	Decomposed to clay contains perhaps remnants of biotite.	"
55	"	"	"	20 ft SE of dike 54 on NE side of railway; 100 feet from bend of Ouachita River.	3′	N & S	Vert	"	"	.....	Less decomposed, contains perhaps remnants of biotite.	"
56	"	"	"	100 ft SE of dike 55 on NE side of railway.	2′	NE	.....	"	"	.....	Completely decomposed.	"
57	"	"	"	20 ft SE of dike 56 on NE side of railway.	1′	N W	.....	"	"	.....	" "	"

58	IV	14	NE of SW	Occur within a distance of 100 ft direc-	.....	.....	.....	Shale and	.....	See dike 62.		Ouachitite
59	"	"	"	tions etc. not given, occur in bed of				Sandstone				
60	"	"	"	Teager Creek 1,500' above (N) the Hot								
				Springs-Malvern road. (Branner.)								
61	"	"	"	In bed of Teager near its bend to the	3'	N 80° E	.....	"	.....	See dike 62.		"
				west above the Hot Springs-Malvern								
				road. (Branner.)								
62	"	"	"	In bed of Teager 40 ft below dike 61	17"	N 30° E	.....	Shale	Kemp	Idiomorphic slightly pleochroitic (yellow to lighter		"
				may intersect dike 61 under the east						yellow) augite; biotite ⅓" and less. Isotropic base,		
				bank of creek. (Branner.)						etc. Augite to biotite as 3 to 1.		
63	"	"	"	Near dike 62.	1'	.....	.....	"	"	Augite up to ¼" zonal; colorless centers yellow		"
										rim. Biotite resorbed, strained, slightly zonal. Iso-		
										tropic base filled with secondary augite, biotite,		
64	"	"	SE of SW	In bed of Teager Creek 700 ft up stream	8½"	E & W	.....	"	"	mag. and apatite, contains inclusion of met. rocks		
				N of Hot Springs-Malvern road. (Bran-						Much altered but recognizable.		Ouachitite
				ner.)								
65	"	23	Cent. of Sec.	Easternmost point of H S R R curve	1'	N & S	Vert	Sandstone	.....	Decomposed showing only flakes of biotite.		"
				800' E of Teager in E bank of cut.								
66	"	"	"	50 ft S of dike 55.	2'	"	"	"	.....	" " " " "		"
67	"	"	SE cor. SW ¼	In bed of small branch 200 ft S of south-	"	"(?)	"	Shale	Kemp	Augite subordinate, biotite abundant, isotropic		"
				ern bend of reverse curve on H S R R						base.		
68	"	"	"	In NE bank of railway cut on eastern-	4'	.....	.....	"	.....	Decomposed to earth.		Igneous
69	"	"	"	most of reverse curves. The sketch	7'	.....	.....	"	.....	" " shows biotite crystals.		Ouachitite
70	"	"	"	shows the relative positions of the	2½'	.....	50° W	Sandstone	.....	" "		Igneous
71	"	"	"	dikes. *Sketch after Branner.*	2'	.....	60° W	Shale	.....	" "		"

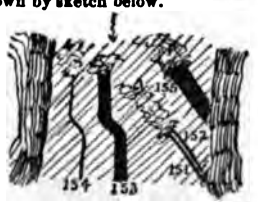
72	"	"	SW of SE¼	In bank on tangent 200' E of eastern-	5" to	.....	70° N	"	.....	" "		"
				most of reverse curves. Branner).	10"							
73	"	"	"	In bank 125' E of dike 72. (Branner).	3' to 14'	.....	10° W	"	.....	" "		"
74	"	"	"	In bank 75' E of dike 73. Branner).	8"	.....	"	"	.....	" "		"
75	"	13	"	.....	.....	.....	.....	.....	Wms.	Augite large idiomorphic crystals filled with titan-		Ouachitite
										ite, magnetite and apatite. Primary and second-		
										ary biotite containing rutile needles. Orthoclase		
										and plagioclase, secondary augite.		
76	"	"	SW of NE¼	In bed of E branch of Teager where a	1'	W NW	.....	"	Kemp	Altered beyond recognition.		Igneous
				small stream enters from NE.								
77	"	"	"	Dike in small stream mentioned above.	"	"	.....	"	.....	Appears dense and shows no biotite crystals.		Fourchite ?
78	"	"	"	In line with dike 76 and 50' W N W of it								
				Three feet S of dike 77 and parallel to	"	"	.....	"	.....	" " " " "		"
				it. Shale strikes N S.								

79	IV	18	SW of NE	In bed of same stream 500′ further up (SE) than dike 78. This dike is somewhat serpentine.	6″	E & W	.....	Shale	Kemp	Augite altered beyond recognition.	Igneous ?
80	"	"	NW of SE	In bed of same stream 500′ further up (SE) than dike 79.	2′	N & S	60 W	"	"	Altered beyond recognition.	"
81	"	"	"	In bed of same stream 90′ further up (SE) than dike 80.	1″	NE	.....	"	.....	.....	"
82	"	"	"	In bed of same stream 70′ further up (SE) than dike 81.	18″	"	.....	"	Kemp	Altered beyond recognition.	"
83	"	"	"	In bed of same stream 400′ further up (SE) than dike 82. This dike appears in bed of stream and separates into two branches forming a <. General direction is NE.	"	"	.....	"	"	Augite colorless. Biotite weathered borders, bleaches and passes into calcite. Dirty green secondary horneblende. Rock much altered.	Amphibole ouachitite
84	"	"	"	In bed of small rill (not mapped) 300′ E of dike 83.	3″	N & S	.....	"	.....	Biotite conspicuous.	Ouachitite
85	"	"	"	100 feet SE of dike 84 dike cutting across shale.	"	E & W	.....	"	.....	Dense and heavy, are easily distinguished from the shale by their peculiar weathering.	Fourchite ?
86	"	"	"	Parallel to dike 85 and two feet S of it. These are at the head of this branch.	"	"	.....	"	.....	" " "	"
87	"	24	Cent NW ¼	Appears in Malvern-Hot Springs road 159 feet E of junction with road running SW to the house of Bob. Johnson. Appears also in stream 50′ SE.	10′	NW	.....	Sandstone	.....	Dike of green rock with feldspar phenocrysts.	Tinguáite
88	"	"	"	In bed of stream 150′ E of where dike 87 crosses it.	15″	ENE	Vert.	Shale	Kemp	Augite, titanite, aggregates of calcite, chlorite, etc., much altered.	Fourchite
89	"	"	NE of NW	In bed of stream 500′ E of dike 88.	"	E & W	.....	"	"	Altered beyond recognition.	" ?
90	"	"	"	In bed of stream 200′ E of dike 89.	1″	"	.....	"	"	Augite, large idiomorphic, includes apatite, altered to green pleochroitic chlorite.	"
91	"	"	"	In bed of stream 50′ E of dike 90.	4″	ENE	.....	"	"	Few faint traces of biotite (macroscopically strong (J. F. W.) remainder altered beyond recognition.	Ouachitite
92	"	"	"	In bed of stream 25′ E of dike 91.	3″	N & S	.....	"	.....	Appears dense and heavy.	Fourchite ?
93	"	"	"	In bed of stream 500′ E of dike 92.	4″	"	.....	"	.....	Imbedded even with surface of shale.	"
94	"	"	"	In bed of stream 75′ E of dike 93, S. of the bend in the Hot Springs-Malvern road.	1′	NNW	.....	"	Kemp	Augite large idiomorphic (yellow to dark yellow outside) twinned on orthopinacoid (100). Biotite, hexagonal, corroded, abundant in base which is isotropic.	Ouachitite
95	"	"	"	In bed of stream 50′ E where dike 94 occurs. Directly opposite the curve, of road and stream.	20′	NW	.....	Sandstone	.....	Fine grained eleolite syenite.	El. Syenite tinguáitic
96	"	"	Cent NE ¼	In small stream 1,000′ SW of E W Kimzey's house 300′ feet SE from the road	15″	"	.....	Shale	Wms	Fine grained eleolite syenite, dark colored like fourchite, showing large idiomorphic, segirite,	"
97	"	"	"	crossing stream to north. 3 dark colored intersecting dikes.	2′	N & S	.....	"	"	apatite, perofskite (?) in small rounded grains	"
98	"	"	"		4′	E & W	.....	"	"	and much calcite and pyrite.	"
99	"	4	Cent SE ¼	At head of gully from J. York's house to Cove Creek 400 feet SE from fork in road near a spring.	4′	NNE	70° W	Sandstone	"	Large orthoclase crystals, biotite of secondary formation, eleolite in hex. sections showing uniaxial character, minute crystals of sodalite (?), magnetite, titanite, all much altered.	Eleolite Tinguáite

100	IV	24	Creat SE ¼	4′ SE of dike 99. Must cut it in the bank.	18″	NE	°°E	Shale	.....	Dense but evidently altered, resembles igneous rock.	Fourchite ?
101	"	"	"	In bed of stream 50′ SE of dike 100, parallel to bed of stream.	.....	E & W	45° S	"	Kemp	Altered almost beyond recognition.	" ?
102	"	"	"	In bed of stream 20′ SE of dike 101.	2′	"	.....	"	"	Altered almost beyond recognition.	" ?
103	"	"	SE of SE	In bed of stream 300′ SE of dike 102.	.....	NW	.....	"	Wms	Augite large and slightly pleochroitic, secondary augite small pleochroitic and green, small secondary biotite, small zonal melanite crystals, orthoclase in base.	Syenitic dike rock somewhat resembling a fourchite.
104	"	"	"	In bed of stream 300′ SE of dike 103.	4′	N & S	60° E	"	"	Augite decomposed somewhat and evidently acted upon by magma. Orthoclase radially arranged and every ray a Carlsbad twin. Isotropic mineral sodalite ? Secondary biotite. Magnetite and titanite.	Tinguáite
105	"	"	"	170′ SE of dike 104, in stream a branched dike E and W. Main dike straight 1 ft. wide; branch to SE 6″ wide.	1′ 6″	Forked E & W SE	.....	"	Kemp	Biotite and magnetite recognizable. Remainder alteration products.	Ouachitite
106	"	25	NE of NE	In stream 800 ft. SE of dike 105 and 350 ft. SE of small branch from N.	6″	ENE	Vert	"	Kemp	Augite large idiomorphic zonal, biotite abundant, magnetite, isotropic base.	"
107	"	"	"	In stream 200 ft. ESE of dike 106.	3″	NE	.....	"	.....	Shows biotite crystals.	"
108	"	"	"	18″ ESE of dike 107.	1″	"	.....	"	.....	" " "	"
109	"	"	"	5″ ESE of dike 108.	1″	.....	.....	"	.....	" " "	"
110	"	"	"	10′ ESE of dike 109. Must intersect it in bank.	5″	N & S	.....	"	.....	Is dense and shows no biotite.	Fourchite
111	"	"	"	100′ ESE of dike 110.	3″	"	.....	"	.....	" " "	"
112	"	"	"	20′ ESE of dike 111.	3′	NNE	.....	"	Wms	Ægirite-like augite; orthoclase; apatite in long dusty crystals of a light violet color; magnetite; titanite.	Syenite
113	"	"	"	In Cove Creek 100′ S of mouth of stream just followed.	15″	"	.....	"	Kemp	Altered beyond recognition but probably fourchite	Fourchite
114	"	"	"	In Cove Creek 20′ S of dike 113.	3′	"	.....	"	"	" " " " " "	"
115	"	"	"	Dike 75 feet north of dike 116 shown in the following group. This dike is near the top of the cliff.	4′	.....	20° SE	"	.....	Large biotite crystals.	Ouachitite
116	"	"	"	Dikes in bluff on west side Cove Creek, ½ mile from station. Positions as in cut.	3′	.....	Vert	"	.....	Dense and heavy.	Fourchite
117	"	"	"		4′	.....	"	"	.....	" "	"
118	"	"	"		.....	.....	Horiz	"	.....	Large biotite crystals.	Ouachitite
119	"	"	"		2′	.....	Vert	"	Kemp	Much altered corroded biotite, secondary augites showing flow structure.	"
120	"	"	"		2′	.....	Horiz	"	Wms	Orthoclase porphyritic, eleolite porphyritic, augite showing weak pleochroism, melanite, arfvedsonite.	Eleolite porphyry
121	"	"	"		2′	N 80° E	20° S	Sandstone	Kemp	Undetermined, too badly altered.	Igneous

122	IV	25	NE of NE	On west bank of Cove Creek 200 ft. SE of the dikes shown above. Lie nearly in bed of creek and only 5ft. apart.	3′	E & W	.....	Shale	Kemp	Altered beyond recognition.	Igneou
123	"	"	"		4′	NE	.....	"	"	" " "	"
124	"	"	"	Dike in the road W of Cove Creek extending from railway 1000 ft. W of Cove Creek to the house marked J. York nearly a mile no th. Dike ⅓ mile from railway.	2′-3′	"	.....	Sandstone	.....	Much altered syenitic dike consists mostly of boulders.	Syenitic dike
125	"	"	SE of NE	Same kind of dike in same road ¼ mile N of railway near the top of the first part of hill.	2′	"	.....	"	.....	Much altered syenitic dike shows in place in road.	"
126	"	"	NE of SE	In ditch N side of railway 300 ft. W of railway bridge over Cove Creek.	1′	"(?)	.....	Shale	.....	Decomposed.	Igneous
127	"	30	Cliff in W½ of NW¼ sec.	A syenitic dike almost at top of hill and belongs with the main mass.	2′	N & S	Vert	Sandstone	.....	Fine-grained gray rock showing feldspar.	Eleolite syenite
128	"	"	"	The relative positions of the dikes in this cliff can be better seen by an inspection of the sketch than by a description.	3′′	E & W	"	"	.....	Comes vertically down the hill from 115 and cuts 118.	Syenite
129	"	"	"		3′	.....	40° N	"	.....	Large crystals of biotite.	Ouachitite
130	"	"	"		2′	.....	Vert	"	Kemp	Altered beyond recognition but is certainly igneous.	Fourchite ?
131	"	"	"		1′	Curved	S	"	"	Rock badly altered, large augites altered, pyrite	"
132	"	"	"	Face of bluff on E side Cove Creek 1600 ft. north of Cove Creek station	6′′	NW	.....	"	.....	Similar to last.	" ?
133	"	"	SW of NW	In small gully entering Cove Creek from E 1200 ft. N of Cove Creek station, situated 75 ft. from its mouth.	3′	.....	.....	Shale	.....	Dark rock.	Igneous
134	"	"	NW of SW	Shows on road from Cove Creek station NE over the hill 600 ft. from station.	3′	WSW	.....	"	Wms.	Orthoclase, large eleolite, leucite, diopside in large crystals, fine-grained base containing feldspar crystals, accessory plagioclase.	Eleolite Tinguáite
135	"	"	SW of NW	On same road 1,000 ft. from station.	1′	"	.....	"	.....	Apparently similar in all respects to above.	"
136	"	"	SE of NW	Boulders SW of crest of hill opposite R. F. Orr's house.	.....	.....	.....	Sandstone	.....	Large augite crystals, resembling that from Fourche Mountain.	Fourchite
137	"	"	NE of NW	On north side of hill 400 ft. N of location 136.	.....	.....	.....	"	.....	Loose piece of same.	"
138	"	"	NW of NW	On S side of hill situated W of J. Neusch's house NW¼ sec. 30.	.....	.....	.....	"	.....	Loose piece of rock showing large biotites.	Ouachitite

139	IV	30	NW of NW	On N side of hill situated W of J. Neusch's house NW¼ sec 30.	.....	.....	.....	Sandstone	.....	Loose piece of rock showing large biotites.	Ouachitite
140	"	"	"	In Cove Creek 400 ft. NE of dike 113 (1,600' NE of big bend to W).	18"	E & W	.....	Shale	.....	Ægirite containing much black opaque material biotite, green eleolite, orthoclase in base, calcite etc	Eleolite syenite
141	"	"	"	West of Cove Creek road at base of hill 250 ft. N of dike 140.	2'	NNE	.....	"	Wms	Pleochroitic augite, orthoclase in base, brown mica, apatite. etc.	Fourchite?
142	"	"	NE of SE	In stream 800 ft. W of Diamond Jo quarry 600 ft. N of railway.	1'	N & S	.....	"	Kemp	Augite large idiomorphic, all else badly altered.	"
143	"	"	SE of NE	In stream 800 ft. W of Diamond Jo quarry 750 ft. N of railway.	10"	SE	Vert	"	"	Altered beyond recognition.	?
144	"	"	"	In stream 800 ft. W of Diamond Jo quarry 800 ft. N of railway.	18"	N & S	80° W	"	"	Augite of two generations, biotite, isotropic groundmass.	Ouachitite
145	"	"	"	In stream 800ft. W of Diamond Jo quarry 825 ft. N of railway. At this point dike No. 144 reappears.	6"	E & W	Vert	"	"	Altered beyond recognition under the microscope	"
146	"	"	"	In same stream 850 ft. N of railway.	6"	NE	"	"	"	Coarse somewhat serpentine, heavy, altered beyond recognition.	Fourchite?
147	"	"	"	In same stream 925 ft. N of railway.	18"-3'	"	"	"	Wms.	Pink eleolite much decomposed, decomposed augite and orthoclase, melonite, calcite, secondary ægirite.	Eleolite porphyry
148	"	"	"	Two intersecting dikes 1,000 ft. N of Ry	8"	S W	"	Sandstone	.....	Dense and heavy.	Fourchite ?
149	"	"	"	The fourchite cuts through the ouachitite.	2'	E&E	"	"	.....	Contains much large biotite.	Ouachitite
150	"	"	"	In same stream 1,100 ft. N of railway.	9"	N & S	"	"	Kemp	Contains large biotites, altered beyond recognition under the microscope.	"
151	"	"	NE of SE	Group of dikes in E branch of same creek 200 ft. NE of junction. Positions shown by sketch below.	2"	NW	.....	Shale	.....	All appear to belong to the fourchite group.	Fourchite
152	"	"	"		2"	"	.....	"	.....	.....	"
153	"	"	"		1'	N	.....	"	.....	.....	"
154	"	"	"		3"	"	.....	"	.....	.....	"
155	"	"	"		18"	N 85° W	.....	"	.....	.....	"
156	"	"	"	Single dike 225 ft. NE of junction.	14"	NW	.....	"	.....		
157	"	"	SE of NE	On same stream as dikes 142 to 150 but separated from them by a band of leucite syenite dike rock. 2000 ft in a straight line to railway.	15'	E & W	.....	.....	Wms.	Rock hard and heavy, augite, magnetite, calcite glassy base (?).	"
158	"	"	"	50 ft further north than dike 157, both dikes very wide.	10'	SW	.....	.....	.....	Similar to last in general appearance.	"



159	IV	30	SE of NE	In stream 80 ft. N of dike 158, probably in syenite.	8″	E & W	Vert	Syenite ?	.....	Evidently an augitic dike.	Fourchite ?
160	"	"	"	In stream 25 ft. N of dike 159.	8″	N & S	Vert.	Sandstone	.....	Evidently an augitic dike.	" ?
161	"	19	SW of SW	In Cove Creek 300 ft NE of dike 141.	6′	E & W	S 40°	....	.....	Green color with large crystals of feldspar.	Tinguaite
162	"	"	"	In Cove Creek 500 ft NE of dike 161. 200 feet S of the mouth of the stream which enters Cove Creek from the east and rises near J. Neusch's barn.	.....	.....	.....	.....	Wms.	Augite mostly altered to calcite but preserving their outline, pyrite, chlorite, calcite making up some parts of the rock entirely.	Fourchite
163	"	"	"	In Cove Creek 75 ft. NE of dike 162.	10′	E & W	S 40°	Met. shale	"	Rock shows indistinct leucites macroscopically, under the microscope orthoclase, ægirite melanite eleolite, cancrinite and is somewhat porphyritic.	Eleolite syenite
164	"	"	SE of NE	Dike in the "branch" on N side 600 ft N of J. F. Moore's house.	.....	.....	.....	.....	.....	Contains eleolite ægirite eudialyte thomsonite etc.	"
165	"	"	"	These are not truly speaking dikes but are exposures of the kind of rock indicated in column XI. where the rest	25′	N E	.....	.....	Wms.	Eleolite melanite schorlomite, ægirite apatite little mica, contains a very white pyrite.	" (Ridgetype)
166	"	"	"		.....	... .	.....	.....	.....	Same but contains much more mica.	(Cove type)
167	"	"	"	of the rock has been decomposed about	2′	NE	.....	.....	Wms.	" " " still more mica (green).	"
168	"	"	"	them. They are all situated in the	.....	.....	.....	.....	"	" " " " " " "	"
169	"	"	"	"branch" and are located as indicated	.....	.....	.....	.....	"	" " " " " " "	"
170	"	"	"	on the map.	.....	.....	.....	.....	.....	" " " " " " "	"
171	"	"	"		.....	.....	.....	.....	.....	" " " " " " "	"
172	"	"	NE of NE	On the N side of the "Cove Hill" near "Sulphur Spring"	2′	N & S?	.....	.....	Wms.	Ægirite, eleolite, biotite, titanite, orthoclase altered, chlorite, pyrite.	"
173	"	18	SW corner of section	In small stream which crosses road 150 ft south of S. W. Fordyce No. 2, old house, within 50 ft of section corner.	5′	.....	.....	Novaculite	.....	Dark colored heavy trap-like rock.	Fourchite ?
174	"	"	SW of SE & SE of SW	Dike 1300 feet long described on p. 185.	6′	N 80° E	Vert	.....	Wms.	For description see page 291.	Amphibole monchiquite
175	"	"	NW of SW	In stream 1000 ft E of house mentioned in 173 and 50 ft S of the syenite mass.	14″	NW	.....	Shale	"	Primary and secondary augite and biotite, melanite, apatite, glass (?). Heavy and trap-like.	Garnetiferous syenite
176	"	"	"	Fourchite covering a considerable area and not a dike. Traced up to syenite, see page 186.	.....	.....	.....	"	"	Idiomorphic crystals of apatite, augite much decomposed and filled with calcite.	Fo'rchite or el. syenite cont. many basic sill't's
177	"	"	SW of NW	In stream which passes house marked S. W. Fordyce No. 3 is a dike bordered by violet contact bands. It is 500 feet N of the house.	18″	SSW	.....	Shale	"	A peculiar syenitic rock of a dark color with a light violet colored border, contains many sections of isotropic minerals which resemble sodalite, glass with a fluidal structure, pseudoleucites (?), also augite and biotite decomposed.	Syenitic rock
178	"	"	"	Large mass of rock similar in position and relations to 176.	.....	.....	.....	.....	"	Decomposed augite-olivine (?) secondary biotite melanite calcite decomposed feldspar etc.	Much alterd eleolite syenite?
179	"	"	"	This stream branches 500 ft above dike 177 and in W branch is a dike 100 ft W of junction.	6″	E & W	Vert	Shale	"	Large primary augite filled with apatite titanite magnetite etc., titanite, orthoclase in base, no primary biotite and little secondary.	Fourchite

180	IV	18	SW of NW	In same branch 10 ft further west.	.....	.....	.....	Shale	Wms.	Appears almost as a stratified rock, has a light color like a syenite, contains microscopically, augite green and blue-green pleochroism arranged in bands and gives stratified look to rock, secondary biotite very pleochroitic, great quantities of titanite in small crystals, magnetite.	Syenite or a much metamorphosed sedimentary rock.
181	"	"	"	In the next branch, middle branch, to the east 400 feet from junction.	2′	E & W	.....	"	.....	Heavy rock small crystals.	Fourchite?
182	"	"	"	In same branch 25 ft further north.	2′	"	.....	"	.....	" " " "	"
183	"	"	"	In same branch 200 ft further north. This is probably in line with the green tinguáite to the west. This number is used for the whole dike.	.....	N 85°W	.....	"	.....	A dark porphyritic rock.	Tinguáite
184	"	"	"	In easternmost branch 300 ft from junction.	2′	E & W	.....	"	.....	Has a stratified appearance.	Syenitic.
185	"	"	"	In same branch 20 ft N of dike 184.	2′′	Serpentine	.....	"	.....	Nothing known about its constitution.	Igneous
186	"	"	SE of NE	In stream which enters Cove Creek opposite the house of J. F. Moore No. 1, 2,000 ft from Cove Creek.	2′	E & W	.....	Syenite	Wms.	Syenite of a light color cutting the eleolite cancrinite syenite.	Eleolite syenite
187	"	"	"	In same stream about 25 ft further N than dike 186.	4′	.....	.....	"	.....	Dike of dark almost black rock including pieces of eleolite syenite and eleolite garnet syenite (the section was lost so that the rock was not determined microscopically.)	Igneous
188	"	"	NE of SE	On south bank of Cove Creek 50 ft east of dike 189.	20′	SSW	.....	Ægirite rock	Wms.	Rock contains large paramorphs of hornblende (?) after ægirite and is much decomposed.	Ægirite eleolite syenite
189	"	"	"	In bed of Cove Creek west of house marked J. Thrasher.	.....	.....	.....	Syenite porphyry	.....	Dike of light eleolite syenite in fine-grained eleolite syenite.	Eleolite syenite
190	"	17	NW of SW	Dike on west side of east spur of Cove Mountain.	20′	N & S	.....	Sandstone	.....	Dense black igneous rock traced for 75 ft.	Fourchite?
191	"	"	W ½ of E & W center line	In bed of Cove Creek opposite north end of east spur of Cove Mountain.	50′+	N & S?	.....	Shale	Wms.	Much decomposed, shows small eleolite, decomposed augitic mineral, orthoclase in base, olivine (?) magnetite, calcite, zeolites, decomposition products.	Eleolite syenite
192	"	"	SE of NW	In Cove Creek 400 ft east of mouth of Chamberlin Creek.	.....	"	.....	.....	"	Dark and resembles fourchite but is seen under the microscope to belong to the syenitic rocks. Contains biotite uniaxial, colorless or light green augite (diopside), melanite, orthoclase, nepheline giving good microchemic tests, titanite in large crystals and much of it, magnetite, apatite.	"
193	"	"	"	In Cove Creek at the same point as dike 192.	.....	.....	.....	.....	.....	Same containing large biotite crystals.	"
194	"	"	N ½ of N & S center line	Occurs in road passing school-house W of J. M. Henry's house. It is a mass 200 ft. long lying parallel (?) to the road and is situated 700 ft north of the cross roads, 900 north of school house.	.....	.....	.....	Sandstone	Wms.	Wide band of brown glassy looking rock with large feldspars in it, phenocrysts of orthoclase, augite biotite orthoclase plagioclase (little) and eleolite in base also possibly sodalite (?).	Eleolite tinguáite

195	IV	17	N½ of N & S center line	600 ft north of dike 194 in road, loose boulders, and in place in gully.	.....	.....	.....	Sandstone	.....	Fine-grained syenite in the gully.	Syenitic rock
196	"	"	"	200 ft north of dike 195 in road, loose boulders.	.....	.....	.....	"	.....	Porphyritic syenite and coarse-grained rock.	"
197	"	"	SW of NE	In N bank of Cove Creek in road 300 ft SE of house of J. M. Henry.	10' ?	E & W?	Vert	Shale	.....	Coarse-grained eleolite mica garnet syenite.	El. mica syenite (cove type)
198	"	"	NW of NE	In Cove Creek and E of house on bank marked J. M. Henry No. 1 probably extends WNW onto hill.	10'	ENE	80° N	"	Wms.	Large augite idiomorphic and in grains, orthoclase eleolite titanite, has light veins in it.	El. syenite of dark col'r
199	"	8	SE of SE	In the SE face of the bluff on the N side of Cove Creek opposite the corner	2'	NE	Vert	Sandstone	.....	Dark trap-like rock.	Dark eleolite syenite
200	"	"	"	of sections 7, 8, 16 and 18. See page 188	18"	.....	.....	"	.....	" " "	"
201	"	"	"	of text. The relative positions of these	2'	.....	45° E	"	.....	" " "	"
202	"	"	"	dikes are shown by the sketch.	1'	.....	20° E	"	Wms.	Light colored rock. Under the microscope shows idiomorphic eleolite somewhat decomposed, orthoclase, little plagioclase, green biotite, magnetite, little augite.	Eleolite syenite
203	"	"	"		1'	.....	15° E	"	"	Dark and light rock mixed, light same as dike 202, dark contains melanite and schorlomite, green augite or hornblende blue and yellow-green pleochroism, green augite filled with a network of fine hair-like needles crossing each other at about 60°, transparent crystals in base showing a spheroidal transformation, biotite in large crystals, eleolite not determined but perhaps disguised by disintegration.	Garnet-mica syenite which is probably also eleolite.
204	"	9	SW of SW	In Cove Creek opposite (SE) of dikes 197-201.	1'	NW	.....	"	"	Light colored rock made up of melanite including all sorts of foreign material, orthoclase tabular Carlsbad twins, ægirite yellow and blue-green pleochroism, little plagioclase, eleolite wanting, titanite and magnetite.	Syenite
205	"	"	"	In Cove Creek and near the western end of dike 203	1'	NE	.....	Met shale	.....	Dark and fine-grained possibly metamorphosed shale.	" ?
206	"	"	"	In Cove Creek 300 ft NE of dike 202 and extends SW until it is opposite to it. Not traced all the way.	3'	"	.....	"	Kemp	Traced 30 ft. SW. Fine crystalline form of syenite	"
207	"	"	"	On S bank of Cove Creek 300 ft NE of dike 203. Dike traced by boulders 100' along the side-hill toward NE.	2'	E & W	80° S	Sandstone and Shale	"	Little to be made out about slide.	Ouachitite ?
208	"	"	"	On same bank 75 ft NE of dike 204, parallel to it.	3'	"	.....	"	.....	Similar to last.	"
209	"	17	SE of NE	In a small stream entering Cove Creek 1000 ft E of J. M. Henry's house, 30 ft south of junction.	10'	"	.....	.....	Wms.	Contains large biotite crystals 1¼ in. across and augite 1 in. Under microscope augite large and showing network of inclusions making 75° with each other, biotite, glassy base devitrified showing tendency to eleolite(?), leucoxene, magnetite, apatite	Ouachitite ? or very ferruginous el. sy'te sh'w'g little eleolit

210	IV	17	SE of NE	In same stream 150 ft from Cove Creek.	6′	E & W	.....	.....	Wms.	Dark rock included in a light dike (6′ wide). Microscope shows for dark rock: augite, orthoclase, apatite, magnetite, leucite (?), glassy material.	Eleolite syenite including darker colored rock same kind.
211	"	"	"	" " 200 ft " " "	8′	.....	.....	.....	.....	Dark rock.	Dark el. sy.
212	"	"	"	" " 300 ft " " "	.....	.....	.....	.....	.....	Dark rock.	"
213	"	"	"	" " 350 ft " " " This dike extends nearly 300 ft in a NE direction from this point.	10′	N E	.....	.....	.....	Green phonolitic looking rock.	Tinguáite
214	"	"	NE of SE	From 100 ft east of house marked J. M. Henry No. 4 500 ft straight up the hill to the east, principally boulders.	15′	E & W	Vert.	Sandstone and shale.	.....	Porphyry very similar in appearance to dike 194 perhaps somewhat darker in color.	"
215	"	"	"	400 ft E of Chamberlain Creek in small stream which passes J. M. Henry No. 4	3′′	S E	"	Shale	Wms.	Amphibole strong pleochroism olive green to yellow, strong relief, orthoclase, plagioclase (little), titanite (quantities), apatite, magnetite.	Syenite inclin. to h'rnbl'de di'rite El. Syenite?
216	"	"	"	600 ft further east than dike 215 in same stream.	3′	SSW	.....	Sandstone	.....	Light colored syenite probably eleolitic.	
217	"	"	"	10 ft further east than dike 216 in same stream.	1′	E & W	.....	"	Kemp	Weatered beyond recognition.	Igneous ?
218	"	"	"	200 ft further east than dike 217 in same stream.	3′	"	.....	"	Wms.	This dike is of a dark color and under the microscope appears to be similar to 198 in every respect except that it contains melanite. It contains a light colored band 6 in. wide which consists of augite syenite.	Syenite includ. much melan. with with a band of aug. sen.
219	"	"	"	400 ft NE of dike 218 in same stream, near point where section line 16, 17 crosses stream.	3′	"	Vert.	"	"	Light colored rock. Idiomorphic orthoclase, aegirite idiomorphic and pleochroitic, green; melanite, magnetite and quantities of titanite; eleolite not discovered	Aegyrite syenite.
220	"	"	SE of SE	Dike on Chamberlain Creek a few feet south of the road crossing at the large bend in the road ¼ mile north of J. G. Ethridge's house.	3′	"	"	"	.....	Black rock 3 ft. wide containing a vein of light rock 3 in. wide—probably similar to 218.	Syenite.
221	"	"	SW of SE	In west bank of west branch of Chamberlain Creek at point where the road approaches it closest on the east bank 500 ft north of J. G. Ethridge's house.	2′	"	"	Shale ?	Wms.	Dark rock containing much biotite 1 to 1¼ in. in diameter, melanite, leucoxene, large almost colorless augite, large apatite crystals, biotite often altered to serpentine, magnetite, orthoclase (little); eleolite wanting but the decomposition has gone so far that it might easily have been destroyed. The same is true of olivine.	Ouachitite or eleolite synite (cove type.)
222	"	"	"	At same place as dike 221 and lying 3 feet north of it.	6′	"	"	"	"	Finer-grained and much fresher. Smaller idiomorphic augite of a pinkish color, olivine (?) younger than the augite and showing high index of refraction, green biotite (alt.) filled with black needles, leucoxene, titanite, magnetite, apatite.	Biot. Monchiquite or else ouachitite. It has same tendency towards syenite

223	IV	16	SW of SW	In Chamberlain Creek due north of Tom Ebb's blacksmith shop and 1000 ft E of the U bend.	18″	NW	Vert.	Shale	Kemp	Altered beyond recognition.	Igneous.
224	"	"	"	In same creek 400 ft NE of dike 223.	1′	N & S	"	"	.....	Dark massive fine-grained rock.	"
225	"	21	NW of SW	In Stone Quarry Creek at westernmost point of the first of its large western bends. In line between houses of J. A. Versar and Mrs. Winford.	18″	E & W	"	Sandstone	Wms.	Dark rock containing biotite, eleolite (much), melanite, orthoclase (little), leucoxene, calcite, coarse-grained rock.	Eleolite syenite (cove type.)
226	"	21 29	¼ mile from west end on line.	Occurs in form of boulders which may be traced a quarter of a mile or more. It crosses the "ridge road" 400 ft east of R. F. Orr's house.	10′-15′	NW	.....	Met Shale	"	Contains large phenocrysts of feldspar in dense black groundmass. For minute description see page 264 of report.	Eleolite tinguaite.
227	"	"	On line.	400 ft further E on same road as dike 226	"	"	.....	"	"	Same as dike 226.	"
228	"	"	"	" " " " " 227	"	"	.....	"	"	Same as dike 226.	"
229	"	29	NE of NW	In small stream SSW of J. N. Johnson's house.	3′	N & S	.....	Sandst.	"	Orthoclase, eleolite, biotite, light yellow garnets, leucoxene, traces of augite, yellowish mineral showing optic anomalies (perofskite?).	Eleolite syn ite dike (cont. same minerals as cove type.)
230	"	"	Cent. of NE	Single loose blocks on small S. spur of the hill SE of J. N. Johnson's house, at S edge of the syenite.	.....	.....	.....	"	"	Contains large biotites.	Ouachitite.
231	"	"	SW of NW	In bed of stream which flows S 1000 ft E of the Diamond Jo quarry, dike opposite N edge of quarry.	3′	N & S	.....	Shale.	Kemp	Augite large idiomorphic violet; pleochroism violet to green, much secondary limonite.	Fourchite.
232	"	"	"	10 ft S of dike 231, in same stream.	10′ ?	E & W ?	.....	"	"	Contains much large biotite, in other respects similar to dike 231. It is however much coarser-grained.	Ouachitite.
233	"	"	11 to center line E & W West end.	This is the dike mentioned in the text as lying 200 ft S of Diamond Jo quarry See page 197.	15′	E & W	.....	"	Wms.	Eleolite in hexagonal sections showing distinct cross, ægirite pleochroism green to yellow, brown garnet (melanite); order of formation:-magnetite, melanite, ægirite, eleolite.	El. Syenite dike rock resem. the ridge type.
234	"	"	SW of SW	In railway cut through hill south of Diamond Jo quarry, about 150 ft W of dike 53.	2′	N & S	Vert.	"	.....	Completely decomposed to clay but evidently originally a dike.	Ouachitite ?
235	"	"	"	Same railway cut 15′ further E than dike 234.	6″	"	80° W	"	.....	Completely decomposed to clay but evidently originally a dike.	"
236	"	"	"	Same railway cut 30′ further E than dike 235.	3′	"	.....	"	.....	Completely decomposed to clay but evidently originally a dike.	"
237	"	28	NW of NW	On the side-hill 600 ft N of I. Rowan's house.	10′ +	E N E	.....	"	.....	Decidedly eleolitic in character and like the coarse eleolite syenite dikes.	El. Syenite.
238	"	"	"	On same side-hill dike parallel to dike 237 and 150′ S of it, 450′ from Rowan's.	"	"	.....	"	.....	Decidedly eleolitic in character and like the coarse eleolite syenite dykes.	"
239	"	"	"	On same W bank of Rowan's Branch 600 ft SW of dike 238, loose boulders.	.....	NE	.....	"	.....	Containing large biotite.	Ouachitite.
240	"	"	"	In bed of stream directly S of dike 239 and running steeply up the bank, boulders only.	.....	WSW	.....	"	.....	Narrow dike imperfectly exposed indicated by boulders.	El. Syenite

241	IV	28	NW of NW	350 SW of dike 240 but still in bed of stream.	6′	W S W	N 80°	Shale.	Wms.	Dike almost black, contains orthoclase, eleolite, decomposed biotite, secondary ægirite, leucoxene and perhaps fluorite.	El. syenite porphyritic
242	"	"	"	8 ft SW of dike 241 but parallel to it. This dike extends 1000 to 1200 feet and passes directly S of I. Rowan's house at its east end and stops in the bluff on E side of Stone Quarry Creek at its west end. This dike is 450′ from the Stone Quarry Creek.	10′-15′	"	"	"	"	This dike is the one which is found crossing up over the hill. It consists of monoclinic augite colorless and surrounded with altered zones, eleolite first and second generation, melanite and a light yellow garnet with the melanite in the center.	"
243	"	"	SW of NW	In the bed of Rowan's Branch 250 ft NE of Stone Quarry Creek.	4′	SW	.....	"	"	Dark colored dike with lighter center showing different degrees of cooling in the dike. It contains biotite reddish brown, monoclinic augite showing twins, augite needles of second generation, orthoclase in base, eleolite altered to calcite and zeolites, apatite magnetite and pyrite.	Eleo. mica syenite porphyritic.
244	"	"	"	In same creek 225 ft NE of Stone Quarry Creek and 25 ft SW of dike 243.	8″	E & W	.....	"	Kemp	Altered beyond recognition.	Igneous.
245	III	2	NW	Occurs in loose pieces scattered along the edges of the syenite.	.....	.....	.....	El. Syen.	Wms.	Shows small green ægirite in feldspathic groundmass, large isotropic or uniaxial crystals of hexagonal form containing many needles of rutile (?)	Tinguáite or a metashale.
246	"	16	"	A mass of dark rock 4 ft in diameter surrounded entirely by syenite.	.....	.....	.....	El Syen.	.....	Dark heavy rock.	Monchiq't ?
247	"	"	SW	Occurs imbedded in syenite and appears as a dike 50 ft long.	3′	SE ?	.....	"	Wms.	White non-pleochroitic augite occasionally titaniferous, hornblende brown and pleochroitic, biotite scarce, olivine altered to serpentine, orthoclase into base.	Amphibole monchiqt.
248	"	"	NE	A dike (?) of fine syenitic material in the coarser rock.	2′-3′	N & S	.....	"	"	Ægirite, biotite, orthoclase microperthitic structure, plagioclase little labradorite, garnet (?), pyrrhotite, titanite, hornblende, structure somewhat pegmatitic.	Ægyrite syenite.
249	III A	16	NW of SE	A syenitic vein starting near the N end of Cedar Park and running 500 ft ENE. It cuts across the directions of the augitic dikes.	10′	E N E	.....	"	"	Light coarse-grained rock containing galenite orthoclase, microfelsitic, little plagioclase, biotite altered to chlorite, augite altered, calcite, ore resembling galenite.	Biotite augite Syenite.
250	"	"	"	This dike was traced 150 ft and at its S end is within 20 ft of the E end of 249.	18″	SE	.....	"	"	Augite idiomorphic, small augite in base, small brown hornblende in base, olivine altered to serpentine, magnetite, pyrite, large regular crystals (analcite ?), glass in base gelatinizes and stains.	Amphibole monchiq'te
251	"	"	W½ of S E	This rock lies on the line between the sandstone and eleolite syenite and seems to constitute a border form of the latter. It is in close connection with dike 253.	.....	.....	.....	"	"	Dense blue syenite made by contact of eleolite syenite with the shale, much decomposed, it has the ordinary constituents of augite syenite but the ægirite has decomposed and been replaced by secondary mica (biotite), orthoclase and a devitrified glass appear.	Augite syenite.

252	III A	16	W½ of S E	This dike cuts only sedimentary rock and when it arrives at the eleolite syenite mass seems to merge into it. Similar to the dike rock at Fourche Mt. (?) 60 ft W of dike 251.	.....	.....	.....	Shale	Wms.	Orthoclase microperthitic, quartz (accessory) zircon (?), fluorite yellow, sodalite, hornblende, magnetite, structure somewhat pegmatitic.	Syenite (pegmatitic)
253	"	"	SW of SE	A long dike crossing both Paleozoic rock and eleolite syenite. Can be traced to branch on west. 800 ft long. Lies S of the dikes just described and cuts across them.	10′+	W S W	.....	El. syen.	"	Olivine, secondary biotite, augite, magnetite, chlorite.	Monchiq't.
254	"	"	"	East of the Paleozoic area is a dike of black rock 100 ft from its edge and imbedded in syenite.	39″	.....	.....	"	"	Olivine showing beautiful serpentizing in the cleavage-cracks, present in two generations, augite with beautiful hour-glass structure, some isotropic mineral with high index of refraction and low polarization colors (?), glass giving plenty of salt cubes when treated with hydrochloric acid.	Monchiq't.
255	"	"	"	A mass of monchiquite rock 60x80 feet coarse (256) and fine (255) lying at the boundary of the Paleozoic rock. It extends into it and into the eleolite syenite. It is directly west of dike 254.	.....	.....	.....	"	"	Olivine altered, other constituents also altered.	Monchiq't.
256	"	"	"		.....	.....	.....	"	"	Like last, augites and glass base still preserved.	Monchiq't.
257	"	"	"	Near 255 and lies between it and the sedimentary rock. Porphyritic syenite from same locality, 257 may be a contact rock or a quickly cooled syenite; see page 158.	.....	.....	.....	"	"	May be altered shale which consists of idiomorphic ægirite needles and small crystals of astrophyllite, base undetermined.	Contact rock. ?
258	"	"	"	Vein or dike cutting 295 at right angles.	.....	N & S	.....	"	.....	Segregation or pegmatite dike.	Syenite.
259	"	"	"	Cuts 258 at right angles. Is said to have been assayed in Chicago with results given.	18″	E & W	.....	"	.....	Segregation or pegmatite dike carrying galenite and perhaps also stibnite.	"
260	"	"	"	Dike of decomposed rock traced 150 ft nearly north and south.	4″	N & S	.....	"	Wms.	Lath-shaped feldspar twins (orthoclase or plagioclase), dark minerals all decomposed, remains of eleolite (?).	Syenite ?
261	"	"	SE¼	Near the east edge of the syenite near Jordan Nethercutt's house.	3′	.....	.....	"	"	Eleolite fresh and decomposed, orthoclase, ægirite (giving green color to rock), biotite (?), titanite, apatite.	El. porphyr fine grained.
262	"	"	"	This appears as loose boulders 10 ft east of south end of dike 261 and in tracing these south it is found as a dike of variable texture ranging from coarse-grained holocrystalline porphyry to a fine-grained hypocrystalline black porphyry; see page 146.	5′	N N W	.....	"	"	Fine-grained eleolite syenite (gray) changing to a black porphyry with large crystals of feldspar orthoclase idiomorphic and often very like sanidine, crystals often broken, optic angle not over 4° or 5°, small orthoclase in base, ægirite decomposed and replaced by secondary biotite, fluidal structure of base about the phenocrysts but rather indistinct.	Ægirite tinguaite.
263	"	"	"	Traced 30 ft, it lies 40 ft W of dike 262.	1′+	W N W	.....	"	"	Coarse vein in finer rock, contains orthoclase, eleolite, plagioclase (oligoclase?), isotropic highly refracting colorless mineral (?), ægirite, magnetite.	El. syenite (p'gmatitic)

264	III.	21	NE	Mass of shale included in syenite, just south of section line of secs. 16 and 21.	.....	.....	.....	.....	Wms.	Metamorphosed shale described on pages 128 and 160.	Meta shale.
265	"	"	"	Between west edge of syenite and Lett's mine, it covers perhaps ¼ of an acre and is 300 ft east of the road.	.....	.....	.....	Edge of syenite	"	Orthoclase poorly bounded often showing a confused internal structure first and second generations, large biotite of two generations, hornblende little, apatite and titanite, oxide of iron, it may be a metamorphosed rock and not a porphyry, (see dike 269).	Tinguáite?
266	"	"	"	Monchiquite dike in Lett's mine (see page 157.) Cuts dike 267.	4'	NW	Vert.	Syenite.	"	Somewhat decomposed, contains augite of two generations, hornblende, olivine altered to serpentine, biotite very sparing, glass, apatite, magnetite.	Monchiq'te.
267	"	"	"	Syenitic dike cut by dike 266 in Lett's mine.	1'	N & S	50° S W	"	.....	Similar to that numbered 261.	El. porphyr fine grained
268	"	"	"	Dike 600 ft south of Lett's mine, traced about 100 ft.	8'	NE	Vert.	El. Syen.	Wms	Augite titaniferous, biotite large, hornblende important often surrounding augite, olivine completely altered to serpentine, plagioclase, orthoclase (?), nepheline (?) altered, hauyne glassy base rock gives gelatinous silica and salt cubes when treated with hydrochloric acid and evaporated.	Biotite amphibole monchiq'te
269	"	"	SE	Mass of greenish black rock near the highway which passes west of the syenite. May be metamorphosed rock.	.....	.....	.....	.....	"	Dark porphyritic rock either a contact with the adjacent shale or else a tinguáitic rock, orthoclase small and in a "pavement" structure, magnetite and a highly refracting mineral which appears to be isotropic with slight anomalies (perofskite?), ægirite completely altered to biotite and magnetite.	Tinguáite?
270	"	"	SE	On section line between 21 and 22 found syenite porphyry.	.....	.....	.....	El. Syen.	.....	Similar to dike 269.	Tinguáite?
271	"	22	"	Loose blocks of bluish porphyry not in place, near center of quarter section.	.....	.....	.....	"	.....	Somewhat like the pulaskite.	Syenite porphyry.
272	"	"	NE	Near center N and S line of Sec. 22, 700 ft S of N end, an opening has been made on this dike.	4' 2" top 4' 7" bottom of 15' hole	E & W	80° N	"	Wms.	This dike is described on page 155 and is found to consist of eleolite imbedded in augite, hornblende, magnetite in large lumps, and decomposed olivine.	Amphibole mon. including eleolit. fragments.
273	"	"	"	Half way between this point and house of Geo. Coppack (in N W ¼ of sec. 23.)	1½"	N & S	.....	"	.....	Dark colored. Not further investigated.	Monchiq't.?
274	"	15	SE	Loose pieces of dark rock in SE corner of the section.	.....	loose.	.....	.....	.....	Dark colored. Not further investigated.	"
275	"	14	SW	Loose boulders in road near center SW ¼ of section 14.	.....	mass.	.....	.....	Wms.	For description see page 136; contains plagioclase.	El. syenite.
276	"	"	"	On top of small hill 1000 ft east of road It appears to run east and west and to cross the road 200 ft N of 275 in the form of loose boulders, has been opened in a small "mine," has been traced 1000 ft.	20'-40'	E & W	.....	El. Syen.	"	Olivine as oldest component altered to serpentine, titaniferous augite, hornblende; biotite rarer, glassy base occasionally showing crystallization of feldspar and nepheline; apatite, magnetite titanite.	Amphibole Monchiq'te.

277	III	23	NW	Masses of "blue granite" (porphyritic syenite) on the road 1000′ NE of Geo. Coppack's house.	.....	.....	.....	El. Syen.	Wms.	Porphyritic (idiomorphic) orthoclase microperthitic structure; Carlsbad twins; hornblende, elæolite very doubtful but powder of stone gelatinizes easily with HCl and gives salt cubes; orthoclase in groundmass, titanite, titaniferous magnetite, porphyritic structure.	Porphyritic syenite.
278	"	"	"	Similar rock in rough masses 10 to 20 ft high east of Geo. Coppack's house, they were evidently pressed through the gray granite and the overlying rock and now appear simply as heaps of broken rock representing what was once a dike.	.....	.....	.....	"	"	Similar to 256. Hornblende green and full of inclusions; biotite and ægirite present in small quantities; decidedly porphyritic in appearance.	"
279	"	"	"	Same rock lying south of Geo. Coppack's house.	.....	.....	.....	"	"	Same as preceeding except that some original augites have been altered to mixtures of hornblende and biotite. These three rocks are similar to the Fourche Mountain "blue granite" except in that they contain less augite,	"
280	"	26	Center.	Dike in a small mass of gray syenite in the center of section 26. The syenite seems to have been thrown up on both sides by the monchiquite, this has been opened in a search for gold.	4′	NW	.....	"	"	Augite idiomorphic much altered by decomposition; olivine all gone to calcite and serpentine; in base which gelatinizes with HCl is augite, hornblende, plagioclase (?) orthoclase, perhaps nepheline, calcite magnetite titanite chlorite, found.	Monchiq't.

CHAPTER XIV.

Scheme of Arrangement and General Conclusions.

It appears from the foregoing description of the igneous rocks of Arkansas that they embrace many forms of eleolite syenite and its accompanying rocks which have not been found elsewhere in the world, or, if found, are so poorly exposed and occur so sparingly that they have been but little studied.

So far as the rocks of Arkansas correspond with those described by Brögger in Norway or those described by Machado, Græff, Derby and Hussak from Brazil, or by van Werveke and others from Portugal, names similar to those used by those writers have been adopted, but in many cases no names have as yet been suggested which apply to certain types occurring in Arkansas.

The name *eleolite syenite* has been restricted in this report to the holocrystalline, granitic, abyssal rocks and the dike rocks have been sharply separated from them.

When the structure of the dike rocks approaches that of an abyssal eleolite syenite the rock has been called an *eleolite syenite dike rock.* (Eläolithsyenit Ganggestein) in the same sense that Rosenbusch (Mikroskop. Physiog. Vol. II., p. 279) uses the name granitic dike rocks (Granitische Ganggesteine).

In all these rocks feldspar and eleolite are the important and characteristic constituents.

These dike rocks have been subdivided both according to their structure and the minerals which they contain and the following varieties have been established.

Miarolitic eleolite syenite dike rock (p. 90) which is a miarolitic dike rock containing eleolite but no quartz.

Miarolitic quartz syenite dike rock (p. 93) which contains

quartz (usually secondary) and is decidedly miarolitic in structure.

Pegmatitic eleolite eudialyte syenite dike rock (p. 239) which consists of large pegmatitic crystals and closely resembles some of the dikes described by Brögger.

Pulaskite (*Trachytic hornblende* (*augite*) *syenite dike rock*) (p. 57) in which the trachytic structure is brought out by the form of the feldspars and in which hornblende is more important than augite, but which in other respects resembles Brögger's laurvikite very closely.

Trachytic eleolite syenite dike rock (p. 83) which in macroscopic appearance resembles Brögger's nordmarkite. This rock, according to its constituents and structure, would fall under the group designated by Brögger as foyaite (a name not used by the writer).

Trachytic eleolite cancrinite syenite dike rock (*Diamond Jo type*) (p. 233) is, as its name expresses, a dike rock containing besides feldspar, eleolite and cancrinite among the light colored silicates.

The next class of rocks consists of the truly porphyritic rocks which are grouped as follows:—

Eleolite porphyry which is restricted to a truly porphyritic form of eleolite syenite in which the *eleolite forms the phenocrysts* and orthoclase is of only secondary importance. These have been subdivided according to the dark colored silicates which they contain. They possibly consist of both dike and border types, but are for the present included under one head, since no specimens have been found sufficiently typical of either class to allow of a sharp distinction between the two.

Eleolite tinguáite which is macroscopically still more porphyritic than the eleolite porphyry in its appearance and in many respects resembles the phonolites. It is characterized by the phenocrysts of orthoclase, the eleolite in the groundmass and the holocrystalline and in many cases panidiomorphic character of the latter. The line between it and the eleolite porphyry is drawn with reference to the phenocrysts which the rocks contain and the structure of the groundmasses.

Two types of eleolite tinguáite are recognized, namely, the *dike type* and the *border type*, but the distinction is one of occurrence and not one of structure.

Among the leucitic rocks no trule abyssal forms appear, but the dike form corresponding to the trachytic eleolite syenite dike rock (Diamond Jo type) occurs associated with the latter. This leucite rock is designated in this report as *leucite syenite dike rock* in order to emphasize the similarity between it and the Diamond Jo type of eleolite rock. It is characterized by the phenocrysts of pseudoleucite, eleolite and feldspar. The pseudoleucites are more prominent than the two other light colored constituents. The rock in some cases approaches very closely to a *leucite porphyry* and in other cases has the structure form of a true abyssal rock. The transition is, however, so gradual and so local that the separation into the two groups has not been made in this report and this rock is all classed under the head of leucite syenite dike rock.

Leucite tinguáite is similar to the eleolite tinguáite except that as in the preceding case the pseudoleucites are the most characteristic phenocrysts. The rock has much the appearance of a leucite phonolite, but differs from it in the same way that the eleolite tinguáite differs from the eleolite phonolite. The leucite tinguáite consists of a dike type and border type which differ from each other in the structure of the groundmass. The dike type shows a certain amount of fluidity in the groundmass while the border type is perfectly nonfluidal, and is holocrystalline with a tendency to panidiomorphism in its constituents.

Ægirite tinguáite (p. 367) macroscopically resembles the eleolite tinguáite very closely but differs from it in that microscopically no eleolite is visible in the groundmass. The feldspar is in large tabular crystals and is the only important phenocryst. The base consists principally of minute feldspar and ægirite crystals.

The *peridotite* forms a distinct type of rock and its char-

acteristics have been studied and described (see chapter XI.) by R. N. Brackett.

The augitic dikes belong to the monchiquite group and among them are some rocks which contain olivine and others in which it is wanting. A complete scheme of subdivisions for this group is given on p. 392.

From what has already been stated in regard to the various regions it is seen that in all probability these igneous outbursts all took place about the same time and that although successive and distinct periods of igneous activity are recognizable in each of them they are chronologically not very far removed from each other.

The evidence at hand points to the subsidence at the end of the Cretaceous period as the time when these eleolite rocks were intruded. The country as far north as the mouth of the Caddo in Clark county was submerged during the Cretaceous period and was covered with Cretaceous deposits. (See map in An. Rep. for 1888, Vol. II.) It was then again depressed until all that portion of the state lying along and east of the St. Louis, Iron Mountain and Southern Railway was under the Tertiary sea and was covered with Tertiary material. The igneous rocks were probably intruded during this subsidence for it is natural to assume that by a subsidence of the land a pressure would be exerted upon the molten material below and that when cracks were formed by the sinking of the Paleozoic rocks the igneous material would force its way up into or through them. It is probable that this intrusion of igneous material began early during this subsidence and lasted until near its close, so that some of the rock was intruded either while the Paleozoic rock which covered it was under the Tertiary sea or else but very shortly before that time.

The geographic distribution of the syenitic rocks described above is shown at a glance by an inspection of the following table:—

Geographic Distribution of Syenitic Rocks.

	REGION	FOURCHE MOUNTAIN REGION			SALINE COUNTY		MAGNET COVE REGION			Potash Sulphur Sprgs.	Sporadic Dikes.
	Mineral Composition	Orthoclase. Basic Silicates. Accessory Minerals.		Orthoclase. Quartz. Basic Silicates	Orthoclase. Basic Silicates. Accessory Minerals. (Plagioclase)		Eleolite. Ægirite. Pyroxene. Melanite. Schorlomite. Biotite. Eudialite.			Eleolite. Orthoclase. Basic silicates. Accessory Minerals. (Sodalite)	Orthoclase. Ægirite. Accessory Minerals.
		Eleolite	Little or no Eleolite		Eleolite	No Eleolite	Little or no Orthoclase	Orthoclase	Leucite.		
ABYSSAL ROCKS	Granitic or Trachytic										
	Hypidiomorphic granular.	Eleolite Syenite (Granitic and Gneissy)			Orthoclastic Eleolite Syenite (Trachytic) — Plagioclastic Eleolite Syenite (Granitic)		El. Mica Syenite (Cove Type) (Granitic) — Eleolite Garnet Syenite (Ridge Type)(Granitic) — Miarolitic Eleolite Syenite (Panidiomorphic.)			Eleolite Sodalite Syenite (Granitic.)	
Intrusive Rocks	Granitoid										
	Trachytic Structure Hypidiomorphic Granular	Eleolite Syenite Dike Rock	Pulaskite			Syenite Dike Rock		El. Syenite Dike Rock (Diamond Jo Type)	Leucite Syenite Dike Rock	Eleolite Syenite Dike Rock	
	Miarolitic Structure Panidiomorphic Granular	Miarolitic Eleolite Syenite Dike Rock		Miarolitic Quartz Syenite Dike Rock							
	Pegmatitic Structure Panidiomorphic Granular				Pegmatitic Eleolite Syenite			El. Eudialyte Syenite Dike Rock			
	Porphyritic										
	Porphyritic Structure Holocrystalline Porphyritic				Eleolite Porphyry (El. Idiom)		Eleolite Porphyry.			Eleolite Garnet Porphyry	
Border	Porphyritic										
	Tinguáitic Structure Holocrystalline Porphyritic	Eleolite Tinguáite	Ægirite Tinguáite			Ægirite Tinguáite		Eleolite Tinguáite	Leucite Tinguáite	Eleolite Tinguáite	Ægirite Tinguáite
						Ægirite Tinguáite			Leucite Tinguáite	Eleolite Tinguáite	

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LIST OF ABBREVIATIONS.

Ægir. ting., ægirite tinguáite.
Amph. monch., amphibole monchiquite.
Amph. ouach., amphibole ouachitite.
Campt., camptonite.
El. eudialite sy., eleolite eudialyte syenite.
El. garnet sy., eleolite garnet syenite.
El. mica sy., eleolyte mica syenite.
El. porph, eleolite porphyry
El. sy., eleolite syenite.
El. sy. dike rock., eleolite syenite dike rock.
El. ting., eleoli e tinguáite.
Fourch., fourchite.
Lamph., lamprophyr.
Leuc. porph., leucite porphyry.
Leuc. sy. dike rock., leucite syenite dike rock.
Leuc. ting., leucite tinguáite.
Monch., monchiquite.
Miaro. el. sy., miarolitic eleolite syenite.
Miaro., qu. sy., miarolitic quartz syenite.
Ouach., ouachitite.
Porph., porphyry.
Porph. sy., porphyritic syenite.
Qu. sy., quartz syenite.
Ting., tinguáite.

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